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FLORAL SUCCESSION IN THE PRAIRIE-GRASS FORMATION OF SOUTHEASTERN SOUTH DAKOTA

THE PREVERNAL, VERNAL, AND ESTIVAL ASPECTS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 113

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(WITH THREE FIGURES)

The western part of Iowa, the eastern and northeastern counties of Nebraska, and southeastern South Dakota lie in the drainage basin of the Missouri. This tri-state area is well within the prairie region of that vast and far-reaching prairie province of the middle west. This area is only a part of the Ponca District of POUND and CLEMENTS,[1] being more strictly Dakotan than Nebraskan, and may be considered as representing a transition between the more mesophytic eastern areas of Iowa and those dominantly xerophytic somewhat to the west, with which it shows the closer floristic agreement. Its composition is thus twofold, pointing to the primitive and more xerophytic stages of the past and at the same time prophetic of the mesophytic stages to come. This aberrant character links it strongly to the xerophytic prairie to the west and southwest, from which it is genetically descended, and the prophetic character links it to the more mesophytic prairie of western Iowa, which has encroached ever westward. Under this migration tension from the southeast and east the primitive prairie has retreated, civilization always being a potent factor in this succession.

Study began in this tri-state region in the fall of 1903 at Sioux City, Iowa, and was carried on during that fall and the next summer

[1] POUND, R., and CLEMENTS, F. E., Phytogeography of Nebraska. 1900.

in the contiguous portions of Iowa, Nebraska, and South Dakota. In the fall of 1904, Yankton, South Dakota, became the base station, and for the next three seasons (1904–1907) the work was carried on from that point. During this period the greater part of South Dakota east of the Missouri was visited, and repeated trips were made into contiguous Nebraska and into Iowa, while at the same time detailed study of a restricted area was being prosecuted. This local area upon which study has been focused lies in the township of Yankton and embraces about 49 hectares, being a rectangular strip 1210^{m} north and south by 405^{m} east and west. The topography is uneven and comprises a series of prairie knolls and slopes, separated into two groups by a gentle drainage valley which traverses it in a southwest and northeast direction. The knolls are low and their slopes gentle, scarcely higher than 10 or 15^{m}, with a gradient never exceeding 30 or 40°. The entire area is largely underlaid by glacial gravel and clayey till. The former mainly constitutes the knolls—the humus is here the most shallow, averaging only about 15 to 20^{cm} in depth. Off from the knolls on the level the humus caps the deposit of clayey till. On the lower erosion slopes (25 to 30^{cm}) and in the drainage valley (60^{cm} plus) the humus has accumulated to a greater depth, sufficient in the latter to bury the till beyond the zone of root activity. The humus is in all cases till or gravel modified by atmospheric, organic, and biotic agencies.

To insure uniformity the nomenclature of BRITTON and BROWN'S *Illustrated flora* has been followed, except where it has conflicted with the verification of grasses made for me through the United States Department of Agriculture by Mr. PERCY L. RICKER and Mr. D. A. BRODIE, to whom I am greatly indebted for this courtesy.

This problem has been carried on under the direction of Dr. HENRY C. COWLES, to whom I wish to acknowledge my indebtedness for many valuable suggestions and criticisms during the progress of the investigation.

Geology and topography

To appreciate fully existing conditions, an epitome of the post-Cretaceous geological development of the region is necessary. The Cretaceous was terminated by that great uplift and crustal movement which formed the Rocky Mountains and gave birth to the major

features of the Missouri valley drainage. This movement particularly affected this region by elevating it from an estuary condition to a point considerably above sea-level, and even probably many feet above its present level. This uplift inaugurated a period of vast erosion, and before the advent of the ice the Missouri had cut its present great valley at least 20 to 25^{m} below its present level.

With the Pleistocene came the glaciers. While doubtless there were five periods of glacial advance and recession in the region, we need concern ourselves now only with the second, the Kansan, which spread from the Keewatin center and deposited over this entire region the Kansan drift sheet, obliterating the questionable pre-Kansan. The Illinois, Iowan, and Wisconsin epochs followed successively, only the latter reaching into southern South Dakota, where a lobe of the Altamont moraine pushed down between the Big Sioux and Missouri Rivers, reaching approximately to Vermillion, South Dakota.

The Kansan must have seriously interfered with the established preglacial drainage, greatly rejuvenating it, at least along minor lines. It seems probable also that subsequent erosion mainly sought out previous lines, largely reestablishing the post-Pliocene drainage system. The Wisconsin likewise disturbed and caused a readjustment of this drainage system, which could have differed but little from that previously worked out in the Kansan. Upon this readjustment of the post-glacial Wisconsin drainage topography, there followed the deposition of that much mooted deposit, the loess.

The region divides itself naturally into two great topographic types, the rolling upland prairie and the flood plain, which cuts the prairie in a general northwest and southeast direction. On either side the flood plain is limited by the escarpments of the Missouri. From this flood plain extend the minor flood plains of its tributaries, further dissecting the upland. The vast valley is cut out from 25 to 50^{m} deep in the upland and presents a flood plain varying from a narrow terrace to frequently 10^{km} in width.

The upland now presents an almost perfectly developed erosion topography, predetermined in the Kansas drift sheet and subsequently veneered by the Wisconsin drift and loess deposit. The latter, which frequently has a depth of 50^{m} to the south of the Wisconsin drift area, thins out northward. The escarpment bluffs are

steep and high, but pass back into a complex of gently rounded, semi-detached hills, which present a sinuate or undulating sky line of jumbled peaks; it is a vast mountain system in miniature. Back a few miles from the bluffs these hills pass imperceptibly into the low, rolling prairie hills, which extend with scarcely a variation in either direction. So perfectly is this tributary drainage system established that upon the prairie swamps and "sloughs" rarely occur. The small streams which have threaded the upland are characterized by ravines of depth and precipitousness, especially in the loess, where they usually end abruptly in a bluff, again dividing the upland into a series of ridges, intricately related, which pass back into the low, rolling hills of gentle profile.

Origin of the prairie

The uplift of the Rocky Mountains, which terminated the Cretaceous, introduced a modifying element which exercised an ever-increasing influence upon the climate of the Great Plains region. Intercepting the eastward-moving moisture-laden winds from the Pacific, a decrease in the annual precipitation to the east of the range must of necessity have followed. The greatest reduction would have been nearest the mountains, decreasing to the eastward. When this interior continental land was finally left by the interior sea and opened to migration, invasion must have been in large degree controlled by this graduated distribution of rainfall. The subsequent origin of the Cascades could have served only to accentuate this distributional difference and reduction in precipitation. Under such conditions the Tertiary phytogeographical distribution of this central region must have been adjusted. Whatever the source, it would seem highly probable that while the entire Mississippi valley was occupied by the rich Tertiary forest, the region lying to the west and bounded by the Rocky Mountains and extending northward into Assinaboia was, on account of the low precipitation, denied to tree invasion and came to be occupied by a prairie formation, increasing in its xerophytism westward just as it does today.

Toward the close of the Tertiary (late Pliocene) fossil evidence points conclusively to climatic change. A retrogressive succession of floral waves swept southward under the influence of the gradually

falling temperature of the Pleistocene. In this glacial movement, the plains region, unable to support tree growth, acted as an entering wedge, causing an east and west divergence. One wing of the migration, dominantly coniferous, followed the Rocky Mountains southward; the other, typically deciduous, sought the Mississippi and its tributary valleys as a migration track; while the prairie moved directly toward the Gulf. At the time of maximum ice advance the descendants of the Tertiary forest were mobilized in the southern Appalachians about the Chattanooga region as a center (ADAMS :02), while the prairie formation concentrated in the southwestern United States, with a possible center in the region of northeastern Texas and eastern Oklahoma and southern Kansas.

With final glacial retreat from this region and subsidence of the glacial sea, migration tension was removed and distribution tension became active. The life waves now in succession rolled northward. The content of our flora demands a consideration of the third wave only. A study of the floristics shows indisputably the commingling of forms of diverse geographical affinity. An unmistakable floristic relation, in many cases specific, exists with a southwestern and southeastern center of post-glacial dispersal.[2] To the east and southeast the deciduous forest type becomes increasingly characteristic, while to the west and southwest the plain or prairie type gradually predominates; the region thus lies in the western border of the tension zone in which migration from these two competing centers of distribution meet. From the southeast the dispersal route has been up the Missouri valley; while the northwestern migration has spread diagonally across natural drainage lines, following the upland plains.

Forest invasion of the prairie

When the arborescent elements of the southeastern biota, migrating up the valleys of the Mississippi and of the Missouri and its tribu-

[2] BESSEY ('99, p. 82) says: "There are 66 or 67 species of native trees in Nebraska, and 56 or 57 have advanced to the state from the southeast." MACMILLAN ('92, pp. 653, 721) has shown that 66 per cent. of genera indigenous to the Minnesota Valley are eastern and 62 per cent. southern, while 32.5 per cent. of the total species are of southeastern origin. Of the native trees of South Dakota at least 75 per cent. show indubitable southeastern affinities. The presence of such genera as Opuntia, Cactus, Yucca, Mentzelia, Croton, Bouteloua, Bulbilis, Lygodesmia, and Aplopappus strongly bespeaks the southwestern alliance.

taries, reached the prairie region they were unable to occupy the high lands, but occupied the flood plains and adjacent slopes. There is no evidence to indicate that the then existing topographical and climatic conditions differed radically from those of today. Again these elements have today their most widespread distribution, a condition at once intelligible when related to physiographic development in the working-back of streams and the increase of flood plain. Two salient points may now be noted: the initial and the continuous subsequent preemption of the upland by the prairie formation, and secondly the continuation of initial climatic conditions. The initial causes which operated to restrict tree invasion and ecesis upon these prairie-covered uplands would thus seem to have their duplication in those natural factors which operate to that end at the present time.

Under the discussion of ecological factors of the region it will be shown that there is a coincidence of factors operating most antagonistically against tree growth upon the upland. The almost entire absence of fungi upon the prairie cannot but be significant. The roots of most of these deciduous trees are obligatively provided with symbiotic mycorhiza and the absence of their specific fungus would preclude advance. Hence fungal infection of the prairie soil must precede or at least accompany forest encroachment. Again, the difficulty of seed germination, almost impossible either because of a dense sod or a lack of soil moisture, successfully checks invasion. In consideration of these precarious climatic factors, peculiar edaphic conditions, and the fact that if planted upon the prairie trees thrive, I am led to the view that the question of non-invasion upon the prairie proper is primarily and initially one of pre-occupation and the inability of seedlings successfully to withstand the extremely severe conditions of the first winter's exposure. In the positive and coincident interaction of unfavorable biological and climatic conditions may be found a cause sufficient to account for tree absence upon the prairie and the slow migration of tree species into this region.

While these causes are all sufficient, yet we must not disregard a secondary and artificial though highly cooperative factor, which in recent times must have served in many places to prevent tree establishment. I refer to prairie fires; yet even in the absence of prairie fires for half a century the prairie stands uninvaded except in cases

of physiographic development (BESSEY '99). And again, as the prairie existed as a climatic formation long before these fires, either of Indian or Caucasian origin, swept the prairies, it would appear that this fire factor has been overestimated by many and is in no sense to be regarded as the fundamental factor. That there is, nevertheless, an extremely slow advance of the forest usually through the medium of its forerunner, the shrub association, whose pioneer *Symphoricarpus occidentalis* is followed by *Rhus glabra*, is very evident.

While the above factors are seemingly adequate to account for tree absence upon the western upland prairie, yet in light of the prairie as a natural climatic formation it would seem more proper to make the problem one accounting for the occasional presence rather than the general absence of trees. A future paper is planned to discuss the factors controlling this encroachment.

The period of growth resumption

Not until about the first week in March are climatological conditions at all favorable to an awakening of vegetation, and then only on infrequent days; but the month as a whole is marked by the opening of flower and leaf buds of trees and the beginning of the germination of prevernal annuals and the formation of the basal rosettes of the perennials, though some tide over from the previous season. The prevernal bloomers naturally make most rapid progress, aided by their geophytic habit. Not infrequently the temperature falls below freezing and killing frosts ordinarily result. Light snow storms, which rarely occur, may temporarily retard growth. The conditions become progressively more favorable and pass insensibly into the period of the prevernal flowers.

The usual snows and rains of the early part of the month assure abundant moisture. The chresard, which is about 18 to 20 per cent. in the early days of the month, decreases to about 14 per cent. at the middle, and to about 12 per cent. toward the last of the month, thus giving an average chresard of some 15 per cent. The different exposures of the prairie hills, knolls, and ravines progressively recover from the effects of winter in the following order: southeast to southwest, southwest to northwest, northeast to southeast, and northwest to northeast. The frost clings to the northern exposure in ravines,

Temperature*			Wind*		Rain*			Light*			Soil§			Mean relative humidity†	Relative evaporation‡
Maximum	Minimum	Mean	Prevailing direction	Total movement	Hourly velocity	Days	Mean daily	Total	Relative¶ intensity	Mean cloudiness	Sunshine per cent.	Mean holard	Mean echard**	Mean chresard	
22° C.	−17 C.	2° C.	N. W.	7666	10.3	8	.11cm	3.35cm	.459	5.2	51	21.3%	7.2%	14.7%	75.2	.510

* Data from Yankton, United States Weather Bureau, being the means of ten years (1894–1904). The nearness of the station to the field makes the data very representative.

† Data from Sioux City, United States Weather Bureau, being the mean of 8 A. M. and 8 P. M. observations from July 1, 1889, to December 31, 1903. The station is about 30 miles south of Yankton.

‡ Relative evaporation is determined by the formula: R.E. = saturation deficit × average hourly wind velocity × mean temperature centigrade + 1000. It is recognized that such a result is by no means quantitative, yet it may well serve relatively as an index, invaluable in contrasting the floral aspects.

§ Soil data all from station B, Solidago slope, N. W. exposure. For technique see CLEMENTS, Research methods in Ecology. 1905.

¶ Relative light intensity equals sunshine per cent. of theoretical maximum light intensity as determined for Yankton by method of sun's altitude.

** Determined from an experiment on the Windsor beam. It will be used as an index of the non-available water. The chresard is then directly computed from the holard.

only leaving toward the latter part of the month, particularly when this exposure is forested. On March 16 on a northwest exposure of a prairie knoll the frost was recorded at the following depths: at base of slope 13.97cm, at middle of slope 30.48cm, at crest considerably below 35cm. Thus the base of the exposure recovers much more slowly than the crest, a condition holding equally true for all exposures; hence vegetation starts earlier upon the upper slopes. However, the chresard increases toward the base of the slope. On March 16 the slope in question showed a chresard at the crest of 7.1 per cent., at the middle of 14.1 per cent., and at the base of 18.2 per cent., the differences being more pronounced and the chresard greater than in any subsequent aspect.

The physical conditions of the period are shown in the adjacent table.

Prevernal floral aspect

Floral activity begins only in the first week of April, and is characterized by the

slow and progressive flowering of six forms, extending up to the last week in April, when an apparent break in floral continuity occurs, no forms flowering for a week or ten days. This break very naturally segregates the prevernal floral aspect.

In addition to the floral forms this aspect is conspicuous as the time of appearance of the rosettes of the vernal, serotinal, and autumnal perennials, and seedling annuals of these same aspects. No facies is established, and the tone of the formation is that of winter and early spring, mainly produced by the standing brown stalks of *Solidago rigida*, *Helianthus scaberrimus*, and *Verbena stricta* of the autumnal aspect, which gives everything a brownish cast, enlivened here and there by the mats of *Antennaria campestris* and *A. neodioica*, and at the base of slopes and in depressions by the green of *Poa pratensis* sod. At the base of slopes now and then are to be seen clumps of green produced by the unfolding leaves of colonies of *Symphoricarpus occidentalis*. To complete the aspect, dotted here and there are the floral forms which characterize it. Ruderal species are noticeably absent.

The pertinent climatological conditions of the prevernal floral aspect may be obtained directly from the adjacent table. On only 63 per cent. of the days does the mean average temperature rise above 6° C., with a range between −6° and 29° C. Coupling this with an average soil temperature of 13° C., growth conditions are seen to be far from favorable. The prevailing wind direction is northwest and with a mean

PREVERNAL CLIMATOLOGY

Temperature	Maximum	29 C.
	Minimum	−6° C.
	Mean	11° C.
Wind	Prevailing direction	N. W.
	Total movement	7919
	Hourly velocity	11
Rain	Days	10
	Mean daily	.26cm
	Total	7.87cm
Light	Relative intensity	.547
	Mean cloudiness	4.7
	Sunshine per cent.	63
Soil	Mean bolard	26%
	Mean echard	7.2%
	Mean chresard	12.8%
Mean relative humidity		63.7
Relative evaporation		4.392

hourly velocity of 11 miles, which is not exceeded during the other aspects. Precipitation is slight (7.87^{cm}) and falls on only about 33 per cent. of the days. The average cloudiness of the sky (4.7) is low, and the sunshine (63 per cent.) is correspondingly higher, resulting in a low light intensity (0.547). The saturation deficit is here not at its maximum (36.3), but, augmented by the high wind velocity, evaporation, which must necessarily serve as a rough comparative index of transpiration, is rising in amount. While far more favorable for vegetation, it becomes progressively more so, the last half of the aspect presenting conditions in soil and air noticeably more congenial to growth. The chresard decreases steadily during the aspect from 14.8 per cent. on April 17 to 12.2 per cent. on April 25, and a marked difference in holard was evident at crest (15.8 per cent.), slope (18.4 per cent.), and base (22.6 per cent.) on April 18. The average chresard is 12.8 per cent.

SPECIES OF THE PREVERNAL ASPECT

FACIES.—None.

PRINCIPAL SPECIES.—Antennaria campestris,† Carex pennsylvanica,† Peucedanum nudicaule,† Pulsatilla hirsutissima.*†

SECONDARY SPECIES.—Astragalus crassicarpus,† Peucedanum foeniculaceum,* Draba micrantha, Ranunculus ovalis.

* Not occurring in area proper but in vicinity. † Forming associations.

The earliest flowering form is Pulsatilla and occurs copiously to subcopiously and characteristically upon the upper slopes of the prairie hills. It appears several days earlier upon the south to southwest exposure, which holds equally true for the other prevernal bloomers. The early warming-up of this exposure accounts for the above phenological precocity. But the greatest abundance of these prevernal forms occurs on the north to northeast exposure. Maturation follows close upon anthesis, which likewise holds for all prevernal flowering species.

Pulsatilla is followed by the blooming, during the first week of April, of *Peucedanum foeniculaceum* and *P. nudicaule*. The former with its umbel of yellow flowers is of rare occurrence; but the latter with its umbel of white flowers appears even copiously in restricted plats, and in its distribution occurs mainly upon the upper xerophytic

slopes of prairie knolls where the grasses are bunched and the association more or less open, though rarely seen at the crests; it thus not infrequently exerts a subtone effect at short range. It is perennial by means of its geophytic root. With the elongation of its peduncle and spreading of its umbel in maturation during the last week of the aspect, it becomes more conspicuous and persists thus far into the vernal aspect.

The beginning of the second week of the prevernal aspect sees *Carex pennsylvanica* in full bloom. It occurs copiously, extending well up to the crests of knolls, but more abundantly on lower slopes, yet never influences the tone of the aspect. In places Carex may assume almost facial rank, but always maintains a bunchy or isolated distribution, which, however, is quite general. The peculiar yellowish-green shade of its leaves and its yellow staminate spikes which appear after the stigmas make it conspicuous. It is a perennial of xerophytic tendencies, propagating itself by rootstocks and stolons.

Carex is shortly followed by the flowering of *Antennaria campestris*, and with its white tomentose leaves, scapes, and papillate heads, it gives a characteristic local tone to this floral aspect, even from a distance. It occurs usually gregariously, being one of the two mat-forming species of the formation, and is very generally distributed throughout, facilitated by its perfect adaptation to wind dispersal. The mats themselves may be isolated or gregarious, as many as twenty having been noted in a plat of $64^{sq\ m}$, yet single mats frequently cover $16^{sq\ m}$, averaging about 1000 plants to the square meter. Propagation is by stolons and migration is centrifugal, with a slow but positive occupation. Mats unite and take complete possession of extensive plats, yet it yields before *Poa pratensis*, in no way being able to hold its own against this sod-forming mesophyte.

The prevernal floral aspect of the formation is terminated by the appearance of *Ranunculus ovalis*, *Astragalus crassicarpus*, and *Draba micrantha* toward the end of the third week of April. They appear in bloom almost simultaneously, but in no way contribute equally to the aspect. Draba occurs only where the soil is exposed and the grass is bunched, hence on upper xerophytic slopes, and appears to be forced out whenever a close association is formed. It is an annual of marked xerophytic tendencies, its leaves being basal and heavily

pubescent with stellate hairs. It is scarce and its small white flower inconspicuous, so in no respect does it influence the floral tone. Ranunculus is even more restricted, occurring sparsely on lowest slopes and in depressions on the higher slopes, and is apparently related to a high water content of the soil. Its yellow petals soon fall, and its presence might easily be overlooked in a casual survey of the formation. It is a perennial and is an index of mesophytic conditions. Astragalus, with its racemes of violet-purple flowers, is easily marked in the formation. While generally distributed, its abundance is sparse to subcopious, yet frequently it assumes a gregarious habit. It is a perennial of thickened tap roots which branch above and eventually fragment behind, establishing new individuals. Its migration is slow; dispersal is effected mainly by gophers, which store the fruits for winter consumption. However, ecesis is very certain.

Vernal floral aspect

Toward the last of the first or the beginning of the second week in May there is a floral outburst inaugurated by the blooming of *Nothocalais cuspidata* and *Lithospermum angustifolium*, closely followed by *Castilleja sessiliflora*, *Lithospermum canescens*, *Viola pedatifida*, and *Oxalis violacea*, which marks the inception of the vernal floral aspect. Forms are now progressively added up to about the first week of June, when the aspect is distinctly terminated by the general blooming of certain sod-formers. *Astragalus crassicarpus* and *Ranunculus ovalis* have extended over into this aspect, the former reaching its maximum flowering about the second week in May, thus entering conspicuously into the vernal period. The fruiting scapes of *Peucedanum nudicaule* enter into the tone, while *Antennaria campestris* with its white fruiting heads is now more noticeable than earlier. The deadened brown tone of the prevernal aspect is at last relieved and replaced by the green of the grassy sod, which is rendered somewhat bizarre by the very general distribution of some twenty-eight flowering forms, the largest number occurring in any aspect. No floral facies is developed except in the case of *Poa pratensis* at the base of slopes, and then only in the later part of the aspect. Most of the prairie annuals have by the later part of the aspect ap-

peared and those of the following aspect are now all ready to bloom. Much growth has taken place in the summer perennials and they have apparently outstripped the autumnal forms. Together they overtop the majority of the vernal group, and toward the end of the aspect the large cauline leaves of Solidago and Helianthus of the autumnal aspect render many of the low-statured bloomers quite hidden, except in the very open associations on the highest slopes and crests. Four ruderals bloom in this aspect but have little influence on the formation.

The summary clearly indicates the significant climatological facts. Physiological activity ensues practically throughout the aspect; the temperature range of 31° C. to 2° C., with a mean of 16° C., rarely inhibiting growth. The wind is dominantly from the south and east quarters. It reaches during this aspect a less total movement and so a less mean hourly velocity than in the prevernal, but the atmosphere has a much lower relative humidity; the relative evaporation is thus nearly twice as great. Couple this with the highest light intensity (.704) and the beneficial results of 8.19^{cm} of precipitation on twelve days are much reduced. The chresard shows a marked decrease from 14.1 per cent. on May 10 to 7.4 per cent. on May 22, though the average chresard for the aspect is 10.7 per cent. The base (12.7 per cent.), slope (14.6 per cent.), and crest (8.8 per cent.) on May 22 still showed a gradation in holard, though the distinction of position is less marked than in the prevernal aspect.

VERNAL CLIMATOLOGY

Temperature	Maximum	31 C.
	Minimum	2 C.
	Mean	16 C.
Wind	Prevailing direction	E.
	Total movement	6877
	Hourly velocity	9.2
Rain	Days	12
	Mean daily	.26^{cm}
	Total	8.19^{cm}
Light	Mean cloudiness	5.2
	Sunshine per cent.	73
	Relative intensity	.704
Soil	Mean holard	17.9%
	Mean echard	7.3%
	Mean chresard	10.7%
Mean relative humidity		51.7
Relative evaporation		7.169

SPECIES OF THE VERNAL FLORAL ASPECT

FACIES.—Poa pratensis† (base of slopes and in depressions).

PRINCIPAL SPECIES.—Spiesia Lamberti sericea, Sisyrinchium angustifolium†, Antennaria campestris,*† Spiesia Lamberti, Castilleja sessiliflora.†

SECONDARY SPECIES.—Viola pedatifida,† Oxalis violacea,† Lithospermum canescens, Carex Meadii,† Meriolix serrulata, Hedeoma hispida, Plantago Purshii,† Antennaria neodioica,† Lithospermum angustifolium, Oxalis stricta, Carex festucacea,† Polygala alba, Poa compressa,† Astragalus crassicarpus.*†

TERTIARY SPECIES.—Pentstemon gracilis, Nothocalais cuspidata, Linum rigidum, Lappula texana, Astragalus plattensis, Gaura coccinea, Senecio plattensis, Psoralea esculenta, Vicia linearis, Osmodium molle, Astragalus hypoglottis, Viola cucullata.

RUDERAL SPECIES.—Lepidium virginicum, Melilotus officinalis,† Melilotus alba,† Lappula Lappula.

* From earlier aspect. † Forming associations.

The first week in May is marked by the flowering of *Nothocalais cuspidata* and *Lithospermum angustifolium*. The solitary yellow head of the false calais, frequently 5^{cm} in width terminating a long (20 to 30^{cm}) naked scape, makes it very conspicuous, though it is never more than sparse to subcopious. It is largely confined to loosely sodded ridges and high slopes, and is pronouncedly of xerophytic tendencies. It is perennial by an excessively thickened root. The achenes are heavily provided with pappus, assuring a wide dissemination.

Nothocalais has scarcely bloomed before the puccoons are in flower, *L. angustifolium* appearing several days before the hoary puccoon (*L. canescens*). The former with its terminal leafy racemes of light-yellow flowers and its sparse occurrence remains an inconspicuous element. The hoary puccoon occurs throughout with the other, but more abundantly. Its orange-yellow flowers in a compact leafless umbel make it perhaps the most conspicuous though it is not the most abundant element in the vernal aspect. Both of the puccoons are abundantly pubescent and in their structure and distribution show marked xerophytic tendencies. They are perennials by deep thick roots. The smooth nutlets preclude all but a very limited migration.

Castilleja sessiliflora, *Viola pedatifida*, *Oxalis violacea*, *Sisyrinchium angustifolium*, and *Spiesia Lamberti sericea* bloom pro-

gressively during the second week of the aspect, and together produce a very noticeable change in the floral tone, a change which is further accentuated by the forms that occur later. The yellow tone given by the puccoon becomes dotted here and there by yellow, blue, violet, white, and purple, and a bizarre tone is the result. Castilleja occurs rarely and of a very restricted distribution, being confined to associations upon upper slopes, where its pale-yellow flowers render it always inconspicuous. The thickened perennial roots are parasitic upon the roots of other plants. Many flowering stalks may arise from one root, thus assuming a bunch habit. The high immobility of the seeds, resulting in a very restricted distribution, accounts for its gregarious habit and local occurrence upon the prairie.

Viola pedatifida with its bright-blue flowers and unrestricted distribution and sparse to subcopious abundance exerts a characteristic effect on the vernal tone. The prairie violet is a perennial from a fleshy short rootstock.

Oxalis violacea seems somewhat restricted to middle and lower slopes, where it may occur densely in open, matlike patches, resulting from a slow centrifugal migration through bulb formation coupled with a positive ecesis. Though acaulescent and of low stature, its gregarious habit and rose-purple flowers, with their green background of palmately trifoliate leaves, make it in restricted plots of primary floral importance in the aspect. It likewise occurs sparsely but generally distributed over all parts of the formation, with the exception of crests and Poa sod, where it exerts only a minor effect. The shallow scaly brown bulbs indicate its perennial nature. Dissemination is by propulsion, the few seeds formed being not distantly ejected from the pentalocular ovary by the recurving of the loculicidally dehiscing carpels. In this we have a still further explanation of its gregarious tendency.

Characterized by a general distribution, a subcopious abundance, and the "bunch-habit" of growth which aggregates its many blue and white flowers, *Sisyrinchium angustifolium* becomes of first prominence in the vernal floral aspct. It is perennial by short fibrous rootstocks. It is abundantly fertile, and the smooth ovoid seeds are discharged but weakly by the loculicidally dehiscing tricarpellate capsule.

The stemless loco-weeds, *S. Lamberti* and its somewhat earlier flowering and more abundant silky variety, *S. Lamberti sericea*, are acaulescent perennial herbs from thick deep roots. Their dense spikes of dark-purplish flowers borne on long peduncles, a restricted though subcopious distribution upon the higher slopes, and silky pubescence make them very conspicuous, easily dominating in the aspect. The middle of the aspect is controlled by the variety, but the type, which flowers some ten days later, holds the floral dominance for the remainder of the vernal aspect. The type is decidedly more mesophytic in its structure and distribution, and it seems evident that the variety is very possibly a xerophytic mutant of *S. Lamberti*. Propagation occurs through fragmentation of the perennial root, producing as in Astragalus a gregarious habit. A limited seed dispersal furthers this patchy distribution.

Noteworthy on account of their rarity in the aspect are *Astragalus plattensis*, *A. hypoglottis*, and *Viola cucullata*, all flowering toward the end of the second week in May. The Astragali occur only in open association toward the crest and are strikingly inconspicuous. They are both decumbent and perennial. The two-valved pod of *A. plattensis* is fleshy and dehiscent and its seed dispersal is accomplished through limited propulsion. *Viola cucullata* is noteworthy, as only a single individual has been recorded in the area and that on the middle slope of a northwest exposure, doubtless the result of fortuitous distribution.

The third week is characterized by the blooming of *Antennaria neodioica*, *Carex Meadii*, *C. festucacea*, *Vicia linearis*, *Senecio plattensis*, and *Pentstemon gracilis*. Early in the third week *Antennaria neodioica* flowers; it appears to be more mesophytic than *A. campestris*, occupying the lower slopes, and it occurs less abundantly, but with the fruiting scapes of the earlier species the antennarias are scarcely second to any forms in conspicuousness. *A. neodioica* is a stoloniferous perennial and forms mats, its rosettes living over winter. It is easily distinguished even at a distance by its large and lighter-colored mats, and by the fact that it flowers while the other species is undergoing maturation and distribution.

The carices appear at about the same time toward the last of the week. *C. Meadii*, however, is earlier and occurs sparsely on lower

slopes and is found inclusive in Poa sods. *C. festucacea* occurs likewise on lower slopes, but more abundantly and assumes the "bunch-habit" of growth. Both the carices perennate and propagate vegetatively by rhizomes. They contribute little if any to the floral tone of the aspect.

Florally associated with the carices, as just noted, are *Vicia linearis*, *Senecio plattensis*, and *Pentstemon gracilis*, to which are soon added *Lappula texana* and *Plantago Purshii*. Vicia occurs rarely, is confined to lower slopes, and exerts no tone effect; it is a perennial form and is pollinated by bees. Senecio, also of rare occurrence, seems to be confined to mesophytic portions of the formation. It is conspicuous on account of its numerous yellow heads and ray flowers. But for its limited occurrence it might easily dominate the tone, and in the vicinity of Sioux City it was recorded as controlling the aspect. The achenes are provided with a copious pappus and a wide distribution is assured. It is a perennial, and its scarcity seems to indicate that it is of decidedly mesophytic tendencies; it may be considered prophetic in our area. *Pentstemon gracilis*, though rarely a component in any plot, is an interesting form. It is confined to the mesophytic portions of the prairie and has been noted as abundant in western Iowa. Its rarity in our area is explained as in the case of Senecio; it is a perennial, and its smooth though numerous seeds are limited in their distribution. *Lappula texana*, the hairy stick-seed, is also a minor element, occurring mainly on lower slopes in sparse abundance. It is much branched and its numerous small blue flowers exert but a restricted effect. It is an annual and very fertile, producing numerous nutlets whose margins are each bordered by a single row of bristles with recurved tips; distribution is entirely by aid of animals. It continues to bloom well into the estival aspect. The prairie plantain, *P. Purshii*, is a woolly annual whose indeterminate spikes rise some 20^{cm}. Of copious abundance and of gregarious habit, it frequently becomes conspicuous at short distances. Its flowers bloom progressively up the spike, reaching the maximum in the early estival aspect and continuing well into July. Its highly immobile seeds prevent other than a limited distribution, thus readily accounting for its gregarious habit.

The fourth week of the aspect, about the last week in May, is

remarkable for the general flowering of *Poa pratensis*. *P. compressa* is associated, but occurs sparsely and principally upon the upper slopes. The relative place of these two forms has been hard to determine, but it seems that *P. compressa* occurs as a forerunner of the bluegrass. In its distribution *P. pratensis* is confined to depressions and lower slopes, and is always indicative of the highest soil-water content, the most favorable exposure, and richest humus. In these situations it forms a dense sod, frequently exclusive, which is constantly pushing up the slopes replacing the bunch-grasses, outlying individuals frequently reaching the higher slopes. It is perhaps one of the most mesophytic of prairie forms, and is almost invariably the forerunner of the prairie shrubs, *Symphoricarpus occidentalis* and *Rhus glabra*. It reaches its highest development on the northwest exposure, and it is up this exposure that the flood-plain and ravine forest of this region has made its greatest advance upon the prairie. Poa is the first facies to bloom, but as noted above is of restricted distribution. It is a perennial and propagation is rapid by the abundant rootstocks, which leads to dense sod.

With the bluegrass are successively added *Oxalis stricta*, *Linum rigidum*, and *Polygala alba*. Never very abundant and of low stature, they add but little to the tone of the aspect, as they are overtopped by the oncoming facies of later aspects. Oxalis appears on lower slopes, possessing frequently a gregarious distribution. It may be either annual or perennial. The few seeds are restrictedly dispersed by the dehiscing capsules. Linum is a decidedly xerophytic annual, being a relict of earlier stages. It appears in the open association on the upper slopes and along prairie crests. It is never common and its fugacious petals prevent all but entire inconspicuousness. Its seeds are few and their mobility little. Polygala is sparingly distributed over the lower slopes of prairie knolls, always working up to higher positions with the increase of mesophytic conditions, but it never remains in the Poa sod. It is perhaps one of the best indices of progressive mesophytism among the prairie species. It is a perennial from woody rootstocks. Seeds are borne two in a capsule and migration is very slow.

As the vernal floral aspect is drawing to a close, several minor elements bloom, extending vernal floral activity over into the first

few days of June. *Gaura coccinea, Meriolix serrulata, Psoralea esculenta, Hedeoma hispida,* and *Osmodium molle* now progressively appear. Though flowering during the transition from vernal to estival aspect, these forms reach their maximum display during the early estival; particularly is this true of Meriolix, Hedeoma, and Osmodium. They should be considered transitional species, which appear during the unsettled climatological conditions between the vernal and estival periods, and are not specially indicative of either. Of subcopious occurrence and largely overtopped by leafy stalks of autumnal forms they must be ranked as almost neutral in the floral aspect. *Gaura coccinea* is a relict of more xerophytic stages and occurs primarily though sparsely in the open association of upper slopes and crests. It is an annual and a low and obscure element. It bears a few-seeded indehiscent nut of little mobility. Meriolix may also be considered as a relict of the xerophytic stages of the prairie, having its present distribution limited to the open association along crests and upper slopes, where it frequently occurs subcopiously. Its large yellow flowers make it conspicuous, but only at short range, as low stature relegates it to a sublayer. It is a slightly shrubby perennial from a woody root, producing numerous seeds which are strikingly immobile. It continues blooming up into the autumnal floral aspect, but reaches its maximum in the early estival. Psoralea is rare and of solitary occurrence on middle slopes; add to this its inconspicuous fading-blue flowers and it is scarcely seen upon the prairie by the casual observer. It is a perennial from a large edible farinaceous tuberous root. In the autumnal aspect, breaking off close to the ground, it becomes a tumble-weed. Its rarity is problematical. Hedeoma, a low annual, scarcely ever more than 20^{cm} high, occurs subcopiously and not infrequently copiously upon middle slopes. Its low stature and leafy branches completely hide its abundant small blue flowers, rendering it ever inconspicuous. Osmodium occurs sparsely though quite generally over the whole formation, with the exception of the very crests. It is a perennial with several stalks, terminated by leafy, pendent, scorpioid racemes of greenish flowers, arising from a thick root. It is also quite unnoticeable. The smooth nutlets possess limited mobility.

The estival floral aspect

Marked by a conspicuous decrease of the vernal floral display, a decided climatological change, the flowering of certain sod-formers initiated by *Panicum Scribnerianum* and followed by *Koeleria cristata* and *Stipa spartea*, and the rapid addition of several prominent estival flowers, which all results in a complete shift of the floral tone, the estival floral aspect begins toward the last of the second week in June and extends well up into middle July, when it is terminated by a climatological and floral change even more pronounced.

Toward the end of the vernal aspect the leafy stalks of oncoming facies render the floral tone weak and in places drown it in a sea of dark green; however, the estival forms like Erigeron, Delphinium, Brauneria, Ratibida, Kuhnistera, and others seem to push rapidly above these, forming a higher floral stratum than the vernal, but to be overtopped later on by the still higher stratum of autumnal forms.

With the shifting of climatological conditions, which is very generally appreciated, comes the blooming of *Rosa arkansana*, *Erigeron ramosus*, *Delphinium carolinianum*, and *Brauneria pallida*, which with the sod-formers noted above are always indicative of the inception of the estival aspect. The physical factors of the soil have become less contrasting on the various slopes and between different positions on the same slope; still the south exposure seems slightly earlier. The middle and base of slopes closely approach in absolute water content and are less separated from the crests in this respect than in earlier aspects. Correspondingly there appears a more uniform plant-covering at this time. It is to be noted that the holard is markedly much lower than in the vernal aspect.

During this time Solidago, Helianthus, and Aster have become vegetatively of primary importance and give the general tone of dark green to the aspect. Extending over from the vernal aspect and largely occurring on the upper slopes are *Polygala alba*, which on account of its indeterminate inflorescence blossoms through the the entire estival aspect, Meriolix, and *Gaura coccinea*. Hedeoma and *Oxalis stricta* continue blooming on the middle slopes. The dominating species added in this aspect are *Koeleria cristata*, *Ratibida columnaris*, *Symphoricarpus occidentalis*, and *Verbena stricta*. The floral forms added in this aspect are twenty-one in number, nine

less than appeared in the vernal aspect. It should also be noted that six new ruderals are added. *Panicum capillare* and *Hordeum jubatum* not infrequently attain no small significance. The latter frequently establishes in waste situations exclusive associations. Its permobile awned spikelets being readily carried by wind or animal, its migration is rapid. In the autumnal aspect *P. capillare* becomes detached at the surface, and the large and profusely branched panicles go tumbling over the prairie until lodgment stops the distribution.

In addition to the floral delineation of the estival from the vernal aspect, it is strongly set off by a change in the climatological conditions. With the introduction of hot dry days and prevailing southern winds the estival aspect begins. The precipitation is slightly higher than in the vernal aspect, but its effect is strongly offset by an average mean temperature some 5° higher than in the vernal. The average hourly wind velocity is 0.9 less and the relative humidity 3.4 lower, the lowest of any aspect. Coupled with these conditions is the fact that the relative evaporation is 1.6 higher, the greatest evaporation of any aspect occurring in the estival.

The holard has a slight rise in the aspect due to the heaviest mean daily rainfall of the season. The chresard thus rises to 11 per cent. on June 6 to fall to 8.9 per cent. on June 22 and 6.5 per cent. on July 7. On June 22 distinction of position seemed nearly eliminated, the base, slope, and crest registering a holard of 15.9, 16.1, and 16.6 per cent.

ESTIVAL CLIMATOLOGY

Temperature		Wind		Rain			Light		Soil			Mean relative humidity	Relative evaporation
Maximum	Minimum	Mean	Prevailing direction	Total movement	Hourly velocity	Days	Mean daily	Total	Mean cloudiness	Sunshine per cent.	Relative intensity	Mean holard	Mean echard	Mean chresard		
35° C.	6° C.	21° C.	S. to E.	5839	8.1	13	.31cm	9.29cm	4.7	56	.551	16%	7.2%	8.8%	48.3	8.794

respectively. Yet the average chresard for the aspect (8.8 per cent.) shows a steady decrease from that of the vernal (10.7 per cent.).

SPECIES OF THE ESTIVAL FLORAL ASPECT

FACIES.—Koeleria cristata,† Poa pratensis.*†

PRINCIPAL SPECIES.—Ratibida columnaris,† Amorpha canescens,† Erigeron ramosus,† Symphoricarpus occidentalis,† Verbena stricta,† Festuca octoflora.†

SECONDARY SPECIES.—Brauneria pallida, Delphinium carolinianum, Rosa arkansana, Linum sulcatum, Panicum Scribnerianum, Meriolix serrulata,* Euphorbia marginata, Potentilla hippiana, Plantago Purshii,* Hedeoma hispida,* Polygala alba,* Hedeoma hispida.*

TERTIARY SPECIES.—Stipa spartea, Aristida purpurea, Allionia linearis, Acerates viridiflora linearis, Osmodium molle,* Anemone cylindrica, Physalis heterophylla, Gaura parviflora, Gaura coccinea.*

RUDERAL SPECIES.—Hordeum jubatum, Ixophorus viridis, Panicum capillare, Melilotus alba,* Lappula Lappula,* Verbena bracteosa, Allionia nyctaginea, Potentilla monspeliensis, Melilotus officinalis,* Lepidium virginicum.*

* From earlier aspect. † Forming associations.

Koeleria cristata is a perennial bunch-grass and a very important sod-former, and may be considered one of the forerunners of the blue-grass. It occurs generally distributed higher up the slopes, where not infrequently it may reach facial rank. Above it seems to be encroaching upon the grama and buffalo grasses and so is quite lacking at the crests. *Panicum Scribnerianum* is likewise a perennial of the bunch habit and is closely associated with Koeleria in distribution, but never appears so abundantly as to become a facies. It is evidently more of a mesophyte than the latter and follows it up the slopes. In the formation studied it is mostly confined to the lower part of the middle slopes. It blossoms slightly before Koeleria. *Stipa spartea* is likewise a bunch-grass and the most xerophytic of these three grasses. It is sparsely distributed upon the uppermost slopes and crests and never forms a facies. It must be rated as an unimportant element in sod-establishment in the formation.

Almost coincident with the sod-formers listed above, blooms the prairie rose, *Rosa arkansana.* It is the first woody perennial to bloom and is distributed over upper slopes and crests where in the latter habitat it commonly becomes copiogregarious. Its abundance, large pink flowers, general anthesis, and height make it always one

of the most conspicuous elements of the early estival aspect. Its prominence, however, is of passing duration, as the petals fall after several days and it passes into obscurity. Mobility is limited, resulting largely in the gregarious distribution. With Rosa, blooms *Delphinium carolinianum.* It is a perennial with a thick heavy rootstock, and occurs sparsely as a xerophyte in the open association upon upper slopes and crests. It is closely associated ecologically with the bunch-grasses and invariably seems to follow them. Its single erect stalk, some 6 to 8^{dm} high, bears a large terminal raceme of conspicuous white flowers. Rising thus so conspicuously, these plants seem like sentinels of the prairie and a few individuals are noticeable at some distance. Many seeds are produced, but mobility is slight.

The anthesis of *Erigeron ramosus* usually precedes that of Delphinium but follows that of Rosa, only a day or two separating them. Erigeron is a perennial or annual occurring along upper slopes, where it assumes a copiogregarious habit of growth. It seems quite restricted, few scattering individuals being noted. It is some 7 or 8^{dm} high, with several stalks rising from a single root, which are terminated by spreading corymbs bearing numerous flowers with yellow disks and abundant white rays; thus it is very conspicuous. The achenes are provided with a double pappus, but mobility would seem limited, judging from the gregarious tendency of distribution. Brauneria, though occurring sparsely upon the highest slopes and crests, is one of the most conspicuous early estival bloomers. It is a xerophytic perennial with a large thick root. A single stalk, some 7 or 8^{dm} high, is terminated by a single large head of flowers frequently 5^{cm} across. The numerous long pinkish ligulate ray-flowers surround a large reddish-brown hemispheric head bristling with abundant roughish chaff; in all a very prominent structure. The achenes are crowned with a short-toothed pappus, thus insuring mobility, though of a low degree. It is to be noted that Brauneria has a blooming period of nearly two months, so it remains a conspicuous element even into the following aspect.

Scarcely have these forms flowered, when two species of secondary importance begin to make their contribution to the floral aspect, blooming progressively during the earlier part of the third week of June. They are *Anemone cylindrica* and *Physalis heterophylla.*

These two perennials add little or nothing to the tone of the aspect, as they are of sparse occurrence and decidedly inconspicuous. Anemone occurs rarely though widely on upper and middle slopes. Physalis is of rare occurrence on lower slopes, but would be noticeable except for the pendent inflorescence which hides the yellow flowers beneath the leaves. The former rises some 50 to 60^{cm}, with its exposed cylindrical head of numerous woolly achenes, which are subject to wide dispersal. The immobile fruit of the latter and its ventral position cooperate to insure a very restricted dissemination.

The last days of the third week and early part of the fourth are marked by the general flowering of three forms, *Ratibida columnaris*, *Symphoricarpus occidentalis*, and *Verbena stricta*, all of primary importance. *Gaura parviflora*, *Linum sulcatum*, and *Allionia linearis*, three flowering forms of minor significance, are added at about the same time. Linum is an annual some 40^{cm} high, occurring sparsely upon the lower slopes. Its humble place in the floral tone is largely due to its limited occurrence, for its yellow flowers (1.5^{cm} in diameter) would otherwise make it a notable element. Gaura is noteworthy mainly as a matter of record, a few specimens only being noted on the middle slope of a northwest exposure. It is an annual and frequently reaches a height of 1^{m} or more. Allionia is a perennial occurring rarely upon middle slopes. The straw-colored involucre incloses one to three small purplish flowers and it is always of minor prominence. The anthocarpous fruit has little mobility. About this time are also added two sod-forming species, *Festuca octoflora* and *Aristida purpurea*. Aristida is of rare occurrence and contributes little to the floral aspect or plant covering. Festuca, on the other hand, is a sod-former of some significance upon lower and middle slopes, being easily replaced however by Poa, which seems to follow it. It is apparently a pioneer form, taking rapid possession of available ground in the open association by means of its heavy, thick, matlike sod.

In Ratibida the long yellow ligulate ray-flowers first spread about June 20, but it is not until several days later that there is a general display and the tube flowers of the columnar disk begin to open. They flower first in a band at the base of the indeterminate head, progressing up at the rate of about 3 to 5^{mm} a day. The plants are

some 7.5^{dm} high, and each of the branches is terminated by a very striking head; yellow drooping rays, 6 to 9 in number and frequently 3^{cm} long, surround a deep-brownish columnar head some 4^{cm} high. The prairie cone-flower occurs copiously upon lower and middle slopes, extending crestward (*fig. 1*). In the former locations it frequently assumes almost facial rank and gives a bright-yellow tone to the entire floral aspect. It is a prolific and continuous bloomer, dominating the aspect through the month of July and the greater part

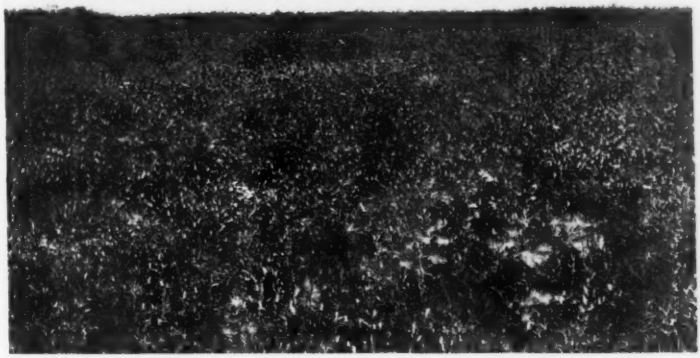

FIG. 1.—Late estival aspect; *Ratibida columnaris* upon a middle slope; the ruderal *Hordeum jubatum* in right foreground.

of August, and extending up to the middle of September. Ratibida is a perennial from a thick root. The achenes are provided with a diminutive pappus of one or two teeth, and so lack of mobility and great fertility result in its copious abundance in restricted localities. It should be recorded that a few specimens with reddish-brown rays having yellow tips and bases have been noted.

At about the time Ratibida is spreading its neutral ray-flowers the earlier flowers of Symphoricarpus appear, reaching their maximum flowering two or three weeks later. The wolfberry is of restricted

distribution, occurring gregariously at the base of slopes and in mesophytic depressions; frequently outlying individuals are found. In the former situations it ranks not infrequently as a facies. It is the largest of the woody perennials of our area, being a profusely branched shrub frequently 1 to 1.25^{m} tall. It is characteristically associated with the Poa sod, which it follows in the latter's advance upon the prairie; the most advanced occupation is upon the north

FIG. 2.—Late estival aspect; Symphoricarpus association in a depression of a northwest exposure; Poa sod in foreground.

to northwest exposures, where it also first appears (*fig. 2*). It is the forerunner of *Rhus glabra*, which in other parts of the prairie follows it closely, together making up the shrub stage, which is succeeded by the *Quercus macrocarpa* and *Ulmus fulva* association as the forest pushes out upon the prairie. While the numerous axillary clusters of pink flowers are not conspicuous from a distance, the masses of dark-green leaves make the Symphoricarpus association very noticeable. Very few seeds are borne in the white globular berries;

immobility and high ecological demands result in its gregarious habit. The berries are persistent and birds may help somewhat in dispersal.

The last of this group to bloom is *Verbena stricta*. About June 25 the purplish-blue flowers make their appearance at the base of the long (15–30^{cm}) indeterminate terminal spikes in a narrow band, which moves upward day by day at the rate of about 1 to 2^{cm}. The maximum flowering, however, seems to be reached about July 10 to 20.

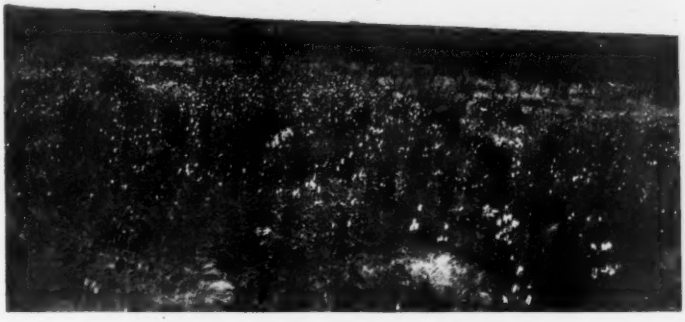

FIG. 3.—Late estival aspect; *Verbena stricta* determining the tone of a lower slope; the white patches are the ruderal *Hordeum jubatum*.

Like Ratibida and for the same reason, it flowers abundantly through July and August and into September. It has a copious and general distribution and not infrequently assumes a dominating influence upon lower (*fig. 3*) and upper slopes as well as crests. It is a perennial from a heavy root and several stalks from the same root give it not infrequently a "bunch" appearance.

During the last days of June and the first days of July, several forms appear to complete the estival floral aspect. In order of flowering they are *Acerates viridiflora linearis*, *Potentilla hippiana*, *Euphorbia marginata*, and *Amorpha canescens*. All assume local

importance except Acerates, reaching their maximum display in the serotinal aspect. Acerates appears rarely and as a solitary xerophyte upon the higher slopes and along crests. It is a perennial with numerous permobile comose seeds, yet its abundance is always low. Its solitary umbel of greenish flowers, which blend with the foliage of the prairie, renders its detection difficult. Potentilla possesses a copiogregarious or a solitary distribution along the middle and lower slopes. It rises 50 to 70^{cm}, with the erect stems terminating in loose cymes of numerous yellow flowers. It thus exercises a local effect in the floral aspect. Through its numerous annual rosettes it also contributes in a limited degree to the plant covering. It is a perennial from a thick root. The numerous achenes are highly immobile, resulting in a limited distribution and the gregarious habit. The white-margined spurge, *Euphorbia marginata*, is an annual which occurs subcopiously on lower slopes and rises erect to a height of 50 to 75^{cm}. The stems bear abundant bright-green leaves and are terminated by three-rayed umbels whose greenish-white flowers are subtended by involucres of numerous white-margined bracts, making the entire umbel a very conspicuous object. *Amorpha canescens* is a prominent perennial shrub (50 to 90^{cm} high) exerting a controlling influence. It is a marked xerophyte and may rise to primary rank upon the crests in a sub-copiogregarious distribution, but rarely occurs upon the lower mesophytic slopes. Its gregarious habit and its abundant and densely white canescent leaflets and densely clustered terminal spikes of dark-blue flowers make it a very striking object, especially when it occurs in such abundance. With sod-establishment it gradually disappears, being a characteristic component of the bunch-grass stage. The indehiscent one-seeded pod is highly immobile.

THE UNIVERSITY OF CHICAGO

UNDESCRIBED PLANTS FROM GUATEMALA AND OTHER CENTRAL AMERICAN REPUBLICS XXX[1]

JOHN DONNELL SMITH

CURATELLA AMERICANA L., var. **pentagyna** Donn. Sm.—Gynaecium e carpellis 5-compositum.

Paniculae saltem in exemplis suppetentibus solitariae vel paucifasciculatae laxiflorae.

Salamá, Depart. Baja Verapaz, Guatemala, alt. 900^{m}, Mart. 1907, *W. A. Kellerman* (n. 6499).

Capparis (§ CAPPARIDASTRUM DC.; Eichl.) **Tuerckheimii** Donn. Sm.—Omnibus in partibus glabra. Folia oblongo-lanceolata longe incurvo-acuminata infra medium angustata ima basi obtusiuscula petiolis plerumque bis terve longiora. Pedicelli gracillimi. Sepala paene sejuncta petalis 4–5-plo breviora. Discus 4-glandularis. Gymnophorium petalis 3-plo fere longius. Ovarium cylindrico-ellipsoideum uniloculare.

Frutex inermis. Folia pergamentacea nitida 7–15^{cm} longa 3–5^{cm} lata, juniora subtus flavescentia costa nervisque rubiginosa venis pellucida, petiolis longitudine multum variis 2–9^{cm} longis ad apicem versus incrassatis, stipulis sicut eae bracteolarum elongato-triangularibus aegre 1.5^{mm} longis margine albidis. Racemus corymbosus, rhachi 2–3^{cm} longa, pedicellis 5–13 circa 5–6.5^{cm} longis apice tetragono-incrassatis. Sepala ovata obtusa 3–3.5^{mm} longa retroflexa. Disci glandulae carnosae. Petala lutea elliptica 14–15^{mm} longa 8^{mm} lata. Stamina numerosa 28^{mm} longa, antheris oblongo-ellipticis 3^{mm} longis. Gynophorium 4–4.5^{cm} longum, ovario 5^{mm} longo spurie 3–5-loculari. Baccae deficiunt.

Inter rupes prope Panzal, Depart. Baja Verapaz, Guatemala, alt. 1200^{m}, Apr. 1907, *H. von Tuerckheim* (n. II. 1746).

Eurya (§ FREZIERA Szysz.) **guatemalensis** Donn. Sm.—Folia supra lucida subtus ferrugineo-tomentosa integerrima oblonga vel lanceolato-oblonga acuminata basi inaequali acuta vel subacuta, nervis lateralibus creberrimis. Flores pedicellati in fasciculum pedunculatam aggregati. Petala glabra porrecta ovata apice obtuso patula sepalis tomentulosis bis longiora. Ovarium elongato-conicum.

[1] Continued from BOT. GAZETTE 44:117. 1907.

Arbor, ramulis subflexuosis, novellis sicut petioli et inflorescentiae ferrugineo-tomentulosis. Folia subcoriacea 10–17^{cm} longa 3–5^{cm} lata supra in sicco laete flavovirentia, costa nervisque supra impressis subtus prominentibus, his inter se 4–8^{mm} distantibus cum intermedio tenuiore brevioreque alternantibus, petiolis 12–14^{mm} longis marginato-canaliculatis inflorescentias paulo superantibus. Pedunculi crassi deciduo-bracteosi 4–7^{mm} longi, pedicellis 5–7 circiter 4^{mm} longis basi bracteola fultis, floribus 8^{mm} longis. Sepala cum bracteolis paulo minoribus suborbicularia concava ferrugineo-tomentulosa. Petala vix cohaerentia 7^{mm} longa basi 4^{mm} lata. Stamina glabra numerosa. Floris masculini filamenta antheras aequantia vel eis paulo longiora, ovarium rudimentarium depresso-pyramidatum stigmatibus carens. Floris feminini filamenta antheris plus minus breviora, ovarium glabrum triloculare petalis bis brevius in stylum 3-fidum sensim attenuatum. Bacca nondum satis matura conica stylum subulatum aequans.—*E. sericeae* Szysz. proxima.

Collium in declivibus aridis prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1350^{m}, Jun. 1907, *H. von Tuerckheim* (n. II. 1824).

Picramnia brachybotryosa Donn. Sm.—Foliola 11–15 plus minus dissociata praeter nervos subtus puberulos glabra obtuse contracto-acuminata, superioribus oblongo-ovatis, inferioribus ovatis, terminali lanceolato-elliptico. Racemi foliis breviores, masculini brevissimi, floribus apetalis tetrameris nonnunquam trimeris glabris.

Fruticulus (e scheda Tuerckheimiana), ramulis petiolis racemis leviter pubescentibus. Foliola per paria deorsum decrescentia petiolo communi 16–24^{cm} longo instructa exmucronulata, superiora 7–9^{cm} longa basi inaequali obtusa, infima 3–4.5^{cm} longa basi subtruncata, terminale remotum basi acutum, petiolulis lateralibus 2–3^{mm} longis. Pedunculus masculinus lateralis 2^{cm} longus racemos binos 9–10^{cm} longos ferens, pedicellis fasciculatis 1–2^{mm} longis glabris, calycis segmentis 3–4 ovalibus 1.5^{mm} longis, staminibus 3–4 calyce bis longioribus. Racemi feminini terminales bini 16–18^{cm} longi, pedicellis solitariis remotiusculis 3–6^{mm} longis glabris, calycis segmentis 3–4 triangularibus vix 1^{mm} longis, ovario ellipsoideo 1.5–2^{mm} longo digyno. Bacca ignota.—Haec a ceteris speciebus tetrameris adhuc cognitis est secernenda, differt enim a *P. tetramera* Turcz. (ex charactere nimis brevi) saltem foliolis inflorescentia calycibus, a *P. quaternaria* Donn. Sm. imprimis floribus apetalis.

In silvis prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1550^{m}, Jun. 1907, *H. von Tuerckheim* (n. II. 1801).

PACHYRHIZUS ANGULATUS Rich., var. **integrifolius** Donn. Sm.—Foliola integerrima subrhomboidea vel inaequilateraliter subrhomboidea sursum acutissime incurvo-elongata infra medium in angulum fere rectum sensim angustata subtus appresse pilosa nervis ferruginea.

Foliolum terminale 63–84^{mm} longum 38–52^{mm} latum, lateralia 55–71^{mm} longa 28–40^{mm} lata.

Cobán, Depart. Alta Verapaz, Guatemala, alt. 1350^{m}, Mart. 1907, *H. von Tuerckheim* (n. II. 1671).

Dalbergia (§ SISSOA Benth.) **tucurensis** Donn. Sm.—Foliola 11–15 oblongo-ovata vel ovata apice acuta et mucronulata basi acuta vel obtusa subtus pallida et minutissime fusco-reticulata. Paniculae axillares foliis bis breviores laxe ramosae. Calycis lobi 4 superiores rotundati infimo acuto bis superati. Stamina 9 monadelpha. Ovarium pilosum.

Arbor, ramulis junioribus petiolis foliis paniculis calycibus fusco-pubescentibus. Folii petiolus communis 21–30^{cm} longus, foliola remote alterna 62–105^{mm} longa 40–48^{mm} lata, petiolulis 3^{mm} longis. Paniculae subpyramidatae pedunculus 3–4^{cm} longus, rami 5–7 remoti, inferiores ramulis computatis 4–5^{cm} longi, pedicellis 1–2^{mm} longis, floribus 6–7^{mm} longis. Calyx 5^{mm} longus usque ad medium lobatus, lobis 2 summis alte connatis quam ceteri bis latioribus, infimo lanceolato tubum superante. Petala calyce paulo longiora, vexillo obovato-orbiculari. Stamen vexillare constanter deficiens. Ovarii stipes stylo bis longior.

Concepción prope Tucurú, Depart. Alta Verapaz, Guatemala, alt. 1000^{m}. Apr. 1907, *H. von Tuerckheim* (n. II. 1712).

Miconia (§ EUMICONIA Naud.; *Glomeratiflorae* Naud.) **oligocephala** Donn. Sm.—Folia satis disparia lanceolata utrinque acuta supra glabra et albido-punctulata subtus cano- et stellato-tomentulosa 3–5-plinervia calloso-denticulata. Paniculae rami simplices in apice vel prope apicem 1- aut 3-capituliferi, floribus tribracteolatis.

Ramuli novelli paniculae calyces ferrugineo- et stellato-tomentulosi. Folium in eodem jugo majus 10–19^{cm} longum paulo infra medium 3–4^{cm} latum alterum triente usque ad bis superans, petiolis 8–18^{mm} longis. Panicula pyramidalis foliis brevior, ramis superioribus unicapituliferis, infimis quaternis prope apicem capitula 2 adjecta sessilia ferentibus, capitulis semiglobosis 5–8-floris, bracteolis ellipticis 3^{mm} longis, floribus 5–6-meris 9^{mm} longis. Calyx companulatus 5^{mm} altus, lobis semioribcularibus scariosis tuberculo 1^{mm} longo extus appendiculatis. Petala obovato-oblonga 4^{mm} longa. Stamina 6^{mm} longa, antheris uniporosis. Bacca depresso-globosa 3^{mm} longa.

Cobán, Depart. Alta Verapaz, Guatemala, alt. 1550^{m}, Aug. 1904, *H. von Tuerckheim*, n. 8686 ex Pl. Guat. etc. quas ed. Donn. Sm. (sub *Conostegia lanceolata* Cogn. olim distributa): Maj. 1907, *H. von Tuerckheim* (n. II. 1781).

Miconia (§ CREMANIUM Benth. et Hook.) **purulensis** Donn Sm.—Simpliciter furfuracea. Folia oblongo-elliptica incurvo-acuminata

basi acuta integra 5-nervia supra glabra subtus nervis furfuracea. Flores pedicellati 5-meri glabri. Antherae biporosae.

Ramuli obtuse tetragoni cum petiolis foliorum subtus nervis panicula fulvo-furfuracei. Folia chartacea plerumque satis disparia 11–20^{cm} longa medio 5–9^{cm} lata nervo utrinque arcte submarginali tenui computato 5-nervia, petiolis 3–7^{cm} longis. Panicula late pyramidalis pedunculo 2.5^{cm} longo adjecto 11–14^{cm} longa congestiflora, ramis ramulisque 2–4-nis, pedicellis 0.5–1.5^{mm} longis, floribus confertis 4.5^{mm} longis. Calyx hemisphaericis 1.5^{mm} altus, dentibus obtuse deltoideis tuberculo punctatis. Petala orbicularia 1.5^{mm}-diametralia. Stamina 3^{mm} longa, antheris rectis oblongo-cuneatis 1^{mm} longis, connectivo infra loculos non producto supra medium geniculato. Stylus in floribus scrutatis nullus. Bacca desideratur.

In silvis circa Purulá, Depart. Baja Verapaz, Guatemala, alt. 1800^{m}, Apr. 1907, *H. von Tuerckheim* (n. II. 1718).

Clidemia (§ SAGRAEA Cogn.) **diffusa** Donn. Sm.—Folia oblongo-ovata incurvo-acuminata basi leviter cordata vel rotundata 5-nervia subintegerrima setuloso-ciliolata. Thyrsi longissimi, ramis remotis uti pedunculus rhachisque filiformibus et ramulis divaricatis, pedicellis brevibus, floribus 5-meris. Calyx campanulatus glaber, dentibus externis minutis.

Ramuli teretes et thyrsi sparsim patenterque pilosi purpurascentes. Folia membranacea in eodem jugo leviter inaequalia 85–125^{mm} longa 35–60^{mm} lata, petiolis supra pubescentibus 25–50^{mm} longis. Thyrsi ex una axilla orti dependentes pedunculo 4–5^{cm} longo adjecto 16–19^{cm} longi ter quaterve trichotomi, rhachis internodiis 35–55^{mm} longis, axibus secundariis inferioribus 20–25^{mm} longis, tertiariis 5–6^{mm} longis, pedicellis 1–3^{mm} longis, floribus 6^{mm} longis. Calycis rubiginosi tubus 2.5^{mm} longus, dentibus deltoideis denticulo 0.5^{mm} longo appendiculatis. Petala flava obovata 3^{mm} longa staminibus paulo longiora. Ovarium vertice conicum, stylo 4^{mm} longo. Bacca globosa 3^{mm}-diametralis.—In sectione floribus constanter 5-meris anormalis.

In monte silvestri prope Purulá, Depart. Baja Verapaz, Guatemala, alt. 1800^{m}, Apr. 1907, *H. von Tuerckheim* (n. II. 1717).

Centropogon (§ SYPHOCAMPYLOIDES Benth. et Hook.) **calochlamys** Donn. Sm.—Glabra. Folia lanceolato-elliptica utrinque longe acuminata argute subcalloso-denticulata. Inflorescentia foliis superata, pedunculis racemoso-confertis paucis. Calycis lobi lanceolato-ovati tubo 4–5-plo longiores corollae tubo aliquantulum breviores. Antherae totae excepto vertice inferiorum nudae.

Fruticulus simplex 22–35^{cm} altus. Folia membranacea 9–16^{cm} longa medio 3–5.5^{cm} lata apice contracto-acuminata basi aequali in petiolum complanatum

10–22^{mm} longum attenuata costa nervis margine subtus sicut petiolus purpurascentia. Pedunculi terminales 2–5 subfasciculati nonnunquam ex axillis superioribus orti 3.5–6^{cm} longi bracteis foliaceis lineari-lanceolati 2^{cm} longis denticulatis fulti. Calycis tubus late hemisphaericus 3–5^{mm} altus, lobi 16–21^{mm} longi 10^{mm} lati denticulati monente cl. repertore in vivo intense violacei etiam in sicco saturato-colorati. Corollae dilute purpurascentis tubus extus glaber intus puberulus 22–25^{mm} longus, laciniae 15–21^{mm} longae. Tubus staminalis pubescens 32^{mm} longus, antheris 7–8^{mm} longis, minoribus apice barbatis, omnibus ceterum glabris. Stigmata semiorbicularia 3^{mm} lata. Bacca semilibera depresso- et compresso-globosa 6^{mm} longa 9^{mm} lata profunde bisulcata styli reliquis apiculata.—*C. Guatemalensi* Robinson proximus differt insigniter calycis lobis permagnis et coloratis.

In monte silvoso prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1650^{m}, Aug. 1907, *H. von Tuerckheim* (n. II. 1893).

Ardisia (§ ICACOREA Pax; Mez.) **verapazensis** Donn. Sm.—Glabra. Folia obovato-oblonga obtuse acuminata in petiolum brevem marginatum attenuata integra coriacea pellucido- et subtus rubro-punctulata. Pedicelli subumbellato-corymbosi gracillimi, floribus inter maximos 5-meris. Sepala extus punctulata intus infra medium lepidotula margine scariosa et nuda. Corollae lobi imbricati epunctati. Filamenta antheris aequalia.

Arbor. Folia 25^{cm} longa 7^{cm} lata, nervis lateralibus primariis utrinsecus 11–15, areolis in utraque pagina obscuris. Panicula corymbiformis 15^{cm} longa 20^{cm} lata, axibus robustis, pedicellis 4–6-nis 12–20^{mm} longis, floribus ebracteolatis. Sepala paene sejuncta dextrorsum tegentia oblongo-ovata 6^{mm} longa obtusa crassa. Corolla ante anthesin 11^{mm} longa vix ultra quartam connata purpurea, tubo 3^{mm} longo intus supra medium perdense aureo-punctulata, lobis orbiculari-ovatis. Stamina medio tubi corollini affixa 6^{mm} longa, filamentis liberis, antheris elongato-triangularibus dorso concoloribus. Ovarium epunctatum ovatum stylo 7^{mm} longo computato 10^{mm} longum. Bacca ignota.—Haec magnitudine florum ceteras species praeter *A. paschalem* Donn. Sm. superat.

In monte silvoso prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1600^{m}, Jan. 1908, *H. von Tuerckheim* (n. II. 2093).

Stylogyne phaenostemona Donn. Sm.—Folia inter minora lanceolata e medio utrinque acuminata coriacea glabra immaculata. Inflorescentia terminalis, floribus 5-meris. Sepala membranacea integra punctulata. Corolla ad usque medium connata, lobis ovalibus punctulatis. Stamina medio tubo inserta cum stylo bene exserta, antheris minutis.

Arbor, ramulis verrucosis, novellis et paniculis fusco-velutinis rubro-punctulatis. Folia 75–90^{mm} longa 28–33^{mm} lata apice basique ipsis obtusiuscula integra utrinque minute areolata, costa supra immersa subtus prominente, petiolis marginatis 4–5^{mm} longis. Paniculae pyramidales 50–65^{mm} longae tripinnatim compositae, saepe ramulos axillares brevissimos terminantes et pseudoaxillares, pedicellis ad apicem versus ramulorum subcorymbosis 3–5^{mm} longis, bracteolis minutis deciduis. Sepala fere sejuncta late ovata 1^{mm} longa margine scariosa et minutissime ciliolata. Corolla 2^{mm} longa, lobis apice rotundatis cum sepalis rubro-punctulatis. Stamina 3^{mm} longa, filamentis liberis antheras ovatas pluries superantibus. Ovarium globosum 1^{mm}-diametrale, stylo 2^{mm} longo, stigmate punctiformi, ovulis circiter 5 in placenta globosa absconditis. Fructus ignotus.—Secundum methodum cl. Mez juxta *S. orinocensem* Mez inserenda.

Cobán, Depart. Alta Verapez, Guatemala, alt. 1350^{m}, Jun. 1907, *H. von Tuerckheim* (n. II. 1814).

Gonolobus (§ DISTEMMA K. Schum.) **prasinanthus** Donn. Sm.—Folia oblongo-ovata incurvo-acuminata sinu obtuso latoque leviter cordata bulboso-pilosiuscula vel glabrescentia. Cymae subumbelliformes, pedicellis pedunculum subaequantibus. Segmenta corollina oblonga calycinis linearibus dimidio longiora. Corona exterior membranacea integra a gynostegio brevissimo libera.

Rami cum inflorescentiis pubescentes vel glabrescentes. Folia supra fere glabra 54–81^{mm} longa 30–39^{mm} lata supra ad ortum limbi glandulis 2 conicis munita, petiolis pubescentibus 30–35^{mm} longis. Pedunculi 15–22^{mm} longi, pedicellis plerumque 4–6 arcte approximatis 12–20^{mm} longis, floribus 18–22^{mm}-diametralibus, perianthio herbacei coloris patente extus puberulo. Calycis partiti segmenta 5–6^{mm} longa a basi 1.5^{mm} lata sensim angustata obtusa, sinubus 1-glanduliferis. Corollae tubus brevissimus, segmenta 8–9^{mm} longa a basi 4^{mm} lata in apicem obtusum scariosum retroflexum sensim angustata nervosa. Corona exterior 0.5^{mm} lata glabra, interior stigma parallele marginans 1^{mm} lata. Gynostegium 1^{mm} longum, stigmate 4^{mm} lato. Folliculi nondum maturi solum visi laeves.—*G. martinicensi* Decne. proximus. Ad *G. fraternum* Schlecht. foliis et perianthio accedens recedit tamen inter alia pedicellis arctius approximatis et corona duplice.

Cubilquitz, Depart. Alta Verapaz, Guatemala, alt. 350^{m}, Jun. 1904, *H. von Tuerckheim*, n. 8711 ex. Pl. Guat. etc. quas ed. Donn. Sm.

Solenophora Tuerckheimiana Donn. Sm.—Pube moniliformi furfuracea. Folia ovato- vel obovato-elliptica acuminata ad basin obtusam altero lato excisa supra tuberculato-furfuracea subtus praeter nervos furfuraceos glabra. Cymae dependentes longissimae semel bis terve 2–3-chotomae, pedunculis axibusque capillaceis elongatis.

Ramuli subtetragoni purpurascentes cum petiolis inflorescentiis floribus plus minus furfuraceo-pubescentes. Folia membranacea plerumque parum interdum valde disparia 125–150^{mm} longa 68–75^{mm} lata nervis et margine purpurascentia, petiolis 45–65^{mm} longis. Cymae pedunculo 40–60^{mm} longo adjecto floribus autem exemptis 70–115^{mm} longae, bracteolis linearibus 6–10^{mm} longis, pedicellis 18–27^{mm} longis. Calycis purpurascentis tubus oblongo-obconicus 14^{mm} longus tertia parte ovario adhaerens, lobi deltoidei 4^{mm} longi dentati. Corollae totae aurantiaceae tubus tubuloso-infundibularis 30^{mm} longus, lobi semiorbiculares 7^{mm} longi integri. Antherae exsertae in quadram 4^{mm} longam atque latam cohaerentes. Glandula disci 2^{mm} crassa integra. Capsula nondum satis matura 10^{mm} longa calyci accrescenti usque ad medium adnata.

In sylva profunda uliginosa ad montem prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1600^{m}, Dec. 1907, *H. von Tuerckheim* (n. II. 2028).

DAPHNOPSIS RADIATA Donn. Sm. in BOT. GAZ. **14**:30. 1889.—Diagnosi adde charactera e specimine fructifero hactenus ignoto sumpta:—Fructus sessilis ovoideus 7^{mm} longus perianthii tubo accrescente marcido supra basin circumcisso inclusus in stylum 2^{mm} longum subabrupte dessinens, pericarpio carnoso.—Arborea.

Cobán, Depart. Alta Verapaz, Guatemala, alt. 1350^{m}, Maj. 1907, *H. von Tuerckheim* (n. II. 1874).

Pilea (§ HETEROPHYLLAE Wedd.) **purulensis** Donn. Sm.—Glabra. Folia inaequilateraliter subovato-lanceolata tenuiter acuteque elongata basi rotundata vel obtusa serrata trinervia, cujusque paris alterum petiolatum altero conformi sessili 3–4-plo majus. Dioica. Cymae masculinae in globum maximum graciliter pedunculatum glomerulatae. Cymae femininae petiolo multum breviores.

Folia tenuiter membranacea supra minute lineolata subtus cystolithis destituta toto margine crenulis antrorsis apiculatis serrata usque ad apicem trinervia venulis tantum subtus manifestis reticulata, basi saepe altero latere rotundata altero acuta, in eodem jugo folio majore 100–150^{mm} longo paulo infra medium 40–55^{mm} lato, petiolis 16–23^{mm} longis, minore 25–50^{mm} longo. Glomerulum masculinum 10–15^{mm}-diametrale pedunculo 18–30^{mm} longo suffultum, pedicellis 2–3^{mm} longis, perigonio 2^{mm} longo glabro scarioso, segmentis apice herbaceis. Cymae femininae 8–10^{mm} longae, pedicellis confertis flores subaequantibus, perigonio rubro-punctulato 1.5^{mm} longo, segmento intermedio cucullato ceteris longiore achenium ovale aequante.

In monte silvoso prope Purulá, Depart. Baja Verapaz, Guatemala, alt. 1800^{m}, Apr. 1907, *H. von Tuerckheim* (n. II. 1707).

Pilea (§ HETEROPHYLLAE Wedd.) **ecbolophylla** Donn. Sm.—Folia quam maxime disparia, alterum obovato-ellipticum vel -lanceo-

latum caudato-acuminatum basi acutum crenato-serratum tri- aut tripli-nervium altero conformi abortivo 12–15-plo majus. Dioica. Cymae femininae petiolis bis breviores.

Caules a rhizomate repente ascendentes 3^{dm} longi simplices. Glabra. Folium in quoque jugo majus pergamentaceum opacum tantum in pagina superiore lineolatum $100–115^{mm}$ longum supra medium $30–42^{mm}$ latum in caudam $15–18^{mm}$ longam serrulatam subabrupte acuminatum triente inferiore integrum, nervo utroque basali paulo infra caudam evanescente, folium alterum nanum $7–8^{mm}$ longum. Cymae femininae solum visae latiores quam longiores patenter dichotomae lineolatae, perianthii segmentis lanceolatis pedicellos subaequantibus achenio ovali 0.75^{mm} longo bis brevioribus.—Ad *P. rhizobolam* Miq. et *P. pansamalanam* Donn. Sm. folio quasi rudimentario accedit.

Ad ripas fluminis *Dolores* dicti, Depart. Alta Verapaz, Guatemala, alt. 350^{m}, Jul. 1901, *H. von Tuerckheim*, n. 7983 ex. Pl. Guat. etc. quas ed. Donn. Sm. (Sub *P. pansamalana* Donn. Sm. olim distributa.)

Pilea (§ DENTATAE; *Glabrae; Brevipedunculatae* Wedd.) **Tuerckheimii** Donn. Sm.—Folia lineari- vel elliptico-lanceolata sensim tenuiterque falcato-elongata basi acuta vel leviter emarginata triente inferiore integra triplinervia supra manifeste subtus subtile lineolata longiuscule petiolata. Dioica. Cymae masculinae petiolos subaequantes recurvae pluries laxe patenterque dichotomae, floribus dissitis pedicellatis.

Caulis a basi oblique radicante erecta ramosa. Folia membranacea leviter disparia $100–160^{mm}$ longa plerumque $25–30^{mm}$ interdum 60^{mm} lata, serraturis antrorsis parvis apiculatis saepe ad callos reductis, nervo utroque basali paulo infra apicem limbi evanescente, lateralibus pellucidis anastomosantibus, petiolis longitudine multum variis $15–43^{mm}$ longis. Cymae masculinae solum visae ad nodos plerumque quaternae $25–45^{mm}$ longae, pedunculo $3–6^{mm}$ longo et ramis complanatis, perigonio bimellemetrali pedicellum circiter bis superante, segmentis lanceolatis minute cucullatis lineolatis, filamentis rubro-punctulatis, antheris exsertis ovatis, connectivo rubicundo.

In monte silvoso haud procul a Cobán, Depart. Alta Verapaz, Guatemala, alt. 1550^{m}, Jun. 1907, *H. von Tuerckheim* (n. II. 1835).

PILEA RIPARIA Donn. Sm. in BOT. GAZ. **19**:11.—Monoica vel dioica. Cymae unisexuales, masculinae adhuc descriptione carentes ex axillis inferioribus ortae singulae aut binae pedunculos implice vel furcato petiolum aequante suffultae pluries dichotomae congestiflorae, pedicellis gracilibus, perigonii segmentis omnibus cucullatis.

Folia usque ad 12–14^{cm} longa 5^{cm} lata, petiolis 15–20^{mm} longis. Cymae masculinae pedunculo computato 40–45^{mm} longae, pedicellis demum 4–5^{mm} longis, perigonio 3^{mm} longo rubro-punctulato.

Ad ripas rivulorum prope Panzal, Depart. Baja Verapaz, Guatemala, alt. 1000^{m}, Apr. 1907, *H. von Tuerckheim* (n. II. 1708).

Myriocarpa obovata Donn. Sm.—Folia glabra oblongo-obovata subabrupte cuspidata basi acuta calloso-subdenticulata inordinate lineolata vix ultra medium tri- aut tripli-nervia. Dioica. Spicae femininae foliis multum breviores pluries dichotomae laxiflorae, floribus singulis vel fasciculatis.

Ramuli glabrescentes verrucosi epidermide in sicco ferruginei. Stipulae lanceolato-ovatae 5^{mm} longae pilosae cito deciduae. Folia pergamentacea opaca 10–16^{cm} longa supra medium 3.5–6^{cm} lata cuspide 8–10^{mm} longa acuminata infra medium integra utrinque praesertim supra cystolithis haud radiatim dispositis conspersa, nervis lateralibus primariis utrinsecus 2–3 arcuatis, venis reticulatis, petiolis 6–13^{mm} longis. Spicae femininae solum visae ad nodos superiores defoliatos solitariae filiformes pedunculo 2–3^{cm} longo computato 6–8^{cm} longae pilosae, floribus ciliatis uti fasciculi pauciflori sparsis, his saepe breviter pedicellatis, calyculo diphyllo aegre 0.5^{mm} longo stipitem paulo superante. Ovarium lanceolatum 1^{mm} longum in stylum attenuatum. Stigma ramo brevi semilunatum.

In silvis profundis prope San Pedro Sula, Depart. Santa Bárbara, Honduras, alt. 800^{m}, Jan. 1887, *Carl Thieme*, n. 5500 ex. Pl. Guat. etc. quas ed. Donn. Sm.

BALTIMORE, MARYLAND

A METHOD FOR THE QUANTITATIVE DETERMINATION OF TRANSPIRATION IN PLANTS

GEO. F. FREEMAN

(WITH ONE FIGURE)

In plant-breeding work, which has engaged my attention for several years, a pressing need has been felt for some means of measuring the drought-resisting quality of individual plants. Morphological characters, such as small leaves, small and few stomata, pubescence, and thick epidermis, are characters which may be assumed to be correlated with drought resistance in that they tend to reduce transpiration and are characteristic of xerophytic plants in general. Moreover, it may be assumed that, other characters of two plants being equal, the one having the lower rate of transpiration per unit of leaf surface would be more suited to the drier portions of the plains region or to withstanding long periods of drought in the more humid districts. Some direct method of measuring the transpiration of plants growing in the field would be of great value therefore to the breeder in selecting for the quality of drought resistance.

At the beginning of our work in alfalfa breeding at the Kansas Experiment Station, no method was known to me which seemed to meet all of the requirements for securing data concerning transpiration for plant-breeding work. It was desired to use the plants selected as mother plants. Therefore they could not be taken up and planted, and the rate of loss of moisture determined by weight. Furthermore, on account of the very long tap roots of alfalfa, it would be impracticable to use a pot large enough to accommodate them without such pruning as would endanger the life of the plant, or at least make them little other than cut stems.

Although it is known that the cut stems of the plant when placed in water do not transpire normally, an attempt was first made to see if the differences sought could be revealed by this method. As a preliminary study and in order to ascertain the effectiveness of the potometer method in determining these individual differences in the

transpiration rate as compared with the same plants growing in the soil, four species were selected which seemed to promise a large range of difference in transpiration. Accordingly, two individuals of each of the following species were selected from young potted plants in the greenhouse: *Coleus Blumei, Chrysanthemum leucanthemum, Pelargonium* sp., and *Portulaca oleracea.* The plants to be used on their own roots were repotted into glass tumblers of suitable size. This was done without disturbing the root system. Evaporation from the soil was prevented by covering the tops of the glasses with a good quality of dental rubber.

For the potometers the plants were cut from the pots at the surface of the soil, one or two of the lower leaves removed, and the stems inserted, through holes in the cork, into bottles containing tap water. The whole stopper was then carefully sealed with paraffin. Each potometer was placed by the side of its corresponding potted plant and the whole series left on a table in a well-lighted room.

During the investigation, which lasted approximately sixty hours, the transpiration rate was found by weighings made at intervals of about one hour during the day. In Table I the average transpiration rate for each plant during the whole of the experiment is shown, and the transpiration rate of the plants on their own roots (normal) is compared with that of the plants in the potometer by reducing the latter to percentages of the former.

TABLE I

	Potted plants on own roots; transpiration in mg. per sq. cm. of leaf surface per hr.	Cut stems in potometer; transpiration in mg. per sq. cm. of leaf surface per hr.	Cut stems in potometer; per cent. of normal transpiration
Daisy	7.21	1.44	20.
Coleus	2.77	0.37	13.3
Portulaca	1.72	0.47	27.3
Geranium	0.65	0.65	100.

It will thus be noted that there is a great difference between the average transpiration rate of a plant on its own roots and that of a cut stem of the same plant placed in water. Moreover, roughly speaking, this difference is greatest in those plants having the highest normal transpiration. This difference, however, may vanish alto-

gether in plants with a low normal rate, as in the case of the geranium. A close scrutiny of Table I is sufficient to demonstrate that although the potometer will give some idea of the purely relative rates in different plants, it cannot be depended upon to give results which are at all comparable with their normal absolute transpiration rates. Thus if we arranged the plants according to their normal transpiration rates, they would stand from highest to lowest thus: daisy, coleus, portulaca, geranium; but if a similar arrangement were made from the results of the potometer experiment they would fall into the following order: daisy, geranium, portulaca, coleus. It was necessary therefore to find some other method for measuring transpiration whereby the plant could be kept on its own roots in the soil and in as nearly normal condition as possible.

As at least a partial solution of this problem, I would suggest the following method for measuring directly the transpiration of plants on their own roots, a method which provides at the same time for supplying them with a constant and uniform current of air. The method is based upon the well-known affinity of phosphorus pentoxid for water, whereby the two are combined and phosphoric acid formed. This compound has long been used as a drying agent and as a means of separating from air or other gases their water-vapor content, for the purpose of measurement. To this end known quantities of air are drawn through U-tubes containing P_2O_5.

Fig. 1 will show the method of setting up the apparatus. The apparatus consists essentially of a glass cylinder of suitable size to be used as a transpiration chamber, two U-tubes for P_2O_5, and an aspirator of known capacity. These are connected by rubber tubing, so that as the water flows from the aspirator a known quantity of air may be drawn through the cylinder and the pentoxid tubes. The cork in the top of the transpiration cylinder has two holes, one for the insertion of a thermometer and the other for the connecting tube to the pentoxid series. The cork for the bottom of the cylinder has two holes; through one is passed a short bent tube serving as an intake for the outside air; the other is to accommodate the stem of the plant. The cork is cut in halves, so that it may be fitted around the plant before inserting in the cylinder. If the stem be not large enough to fill the hole in the cork completely, this may be made close by packing

with vaselined absorbent cotton. The phosphorus pentoxid tubes used were 21^{cm} long and were fitted with glass stop-cocks and with suitable intake and outlet side tubes. The P_2O_5 was arranged in layers held apart by glass wool, so that the air could pass through it freely. Graduated aspirators fitted with stop-cocks at the base, and rubber stoppers at the top, would of course be more suitable,

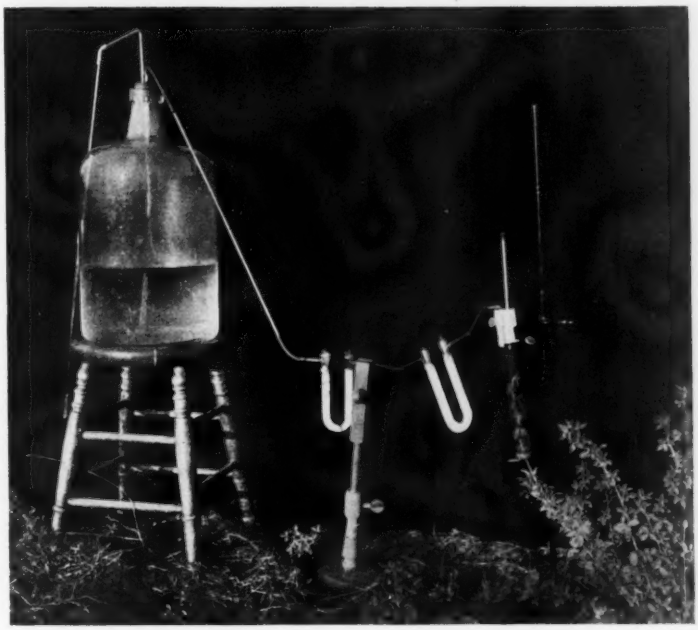

FIG. 1

but in the experiments I conducted 19.5 liter bottles, fitted with two-holed rubber stoppers, for the intake tube and the outflow water syphon, were used with satisfactory results.

For use the U-tubes are filled with P_2O_5, numbered and carefully weighed; the aspirator is filled with water and the whole apparatus set up, care being taken that all the connections are properly made and the joints air tight. The stop-cocks in the U-tubes are turned off, so that no moisture may reach the P_2O_5 between the time of weighing and

the beginning of the experiment. The last operation is the insertion of the stem of the plant into the cylinder. This should be done as quickly as possible and the exact time noted. The stop-cocks in the U-tubes are then turned so as to allow free passage of air, and the water is started running from the aspirator. As the water flows from the aspirator, a steady current of air is thereby drawn into the transpiration cylinder, where it passes over the leaves, out through the outflow tube at the top, thence through the pentoxid tubes, where both the moisture of the normal air and that given off by the plant is absorbed. One tube is usually quite sufficient if it is fresh, but since I used the same tube a number of times without refilling, it was thought best to use a second tube as a guard, and as a means of indicating the exhaustion of the water-absorbing capacity of the first tube. The flow of water from the aspirator was so regulated that each experiment lasted approximately an hour. The area of leaf surface, the cubic contents of the transpiration cylinder, and the capacity of the aspirator in the experiments made were approximately in the proportion of 1:5:500. Of course the leaf surface varied considerably in the different experiments, since it was impossible to obtain the same amount each time. It will thus be seen that the air in the transpiration cylinder was changed 100 times in 60 minutes, or once in every 36 seconds. The rise in humidity in the cylinder due to transpiration of the plant can therefore easily be controlled by regulating the rapidity of the flow of air through the cylinder or by changing the amount of leaf surface inclosed. The exact time when the water ceases to flow from the aspirator is noted, the stop-cocks in the U-tubes are cut off, and the plant severed from the parent stem at the point where it enters the cylinder. The plant may be kept in the transpiration cylinder until ready to be weighed. When the flow of air through the cylinder ceases, the contained air soon reaches the saturation point and the plant is thus kept fresh until ready for weighing and for putting the leaves in the press for area determination.

The increase in weight in the pentoxid tubes gives the sum of the amounts of water transpired by the plant in the given time, plus the water present in the quantity of air used; therefore it becomes necessary to know the exact water content of the air. This may be found by use of the sling psychrometer, the wet and dry bulb

thermometer, or by passing a given quantity of the normal air at the time of the experiment over phosphorus pentoxid in U-tubes in the same manner as in the case of the transpiration experiment itself. I prefer the latter method, as it is more direct and accurate, corrections are not required for altitude, barometric pressure, etc., and it calls for little extra labor to set up the additional apparatus and to run it simultaneously with the other. If all of the aspirators be of the same size, it will simply be necessary to subtract the increase in weight of the tubes used for the normal air from the increase in weight of those used in the plant series to find the actual amount of water vapor transpired by the plant in the given time. By dividing this amount by the product of the area of the leaves and the duration of the experiment expressed in minutes, and then multiplying this quotient by 60, the transpiration rate per hour per unit area is obtained.

The degree of accuracy of this method may be measured by checking it against the transpiration of a cut stem in a potometer or of a plant in a sealed pot. In my experiments I used the cut stem of an alfalfa plant. The leaves were removed from a few inches of the lower part of the stem, which was then inserted in a bottle of water through an opening in the cork which was thoroughly sealed over and around the stem with paraffin. By making several weighings of this plant before and after its use in the transpiration apparatus, its rate of loss of water was determined for the time before, during, and after its inclosure in the cylinder. The net increase in weight in the P_2O_5 tubes, after the weight of water present in the amount of normal air used has been subtracted from their total increase, should of course equal the loss in weight of the potometer during its inclosure in the cylinder. This method of checking was repeated three times with highly favorable results, details of which are shown in Tables II and III.

It will be noted from Table II that the last weighing of the potometer was made at 3:10, or two minutes before it was placed in the cylinder, and that the first weighing thereafter was made at 4:18, or five minutes after the air ceased to pass over the P_2O_5 tubes. The amount of water transpired during these intervals must be subtracted from the total of 0.150 grams as shown in Table II before comparing it with the net gain of the P_2O_5 tubes. Again referring to Table II, it

TABLE II

POTOMETER WEIGHINGS

Time	Total weight: grams	Number of minutes since last weighing	Loss: grams	Loss per min.: grams	Remarks
2:46 P. M.....	108.890	....	.....	.....	
3:10 P. M.....	108.775	24	0.115	0.0048	The rate in normal air before the experiment
4:18 P. M.....	108.625	68	0.150	0.0022	Includes the period during which the plant was inclosed
4:48 P. M.....	108.540	30	0.085	0.0028	The rate in normal air after the experiment

TABLE III

Plant placed in cylinder 3:12 P. M.	
Water stopped flowing from aspirator 4:13 P. M.	
Duration of experiment 61 minutes.	
Total gain in weight of P_2O_5 tubes	0.343 grams.
Amount of water in air used	0.217 grams.
Net gain of P_2O_5 tubes	0.126 grams.

will be seen that for the first of these intervals the rate was 0.0048^{gm} for two minutes or 0.0096^{gm}; and for the second, 0.0028^{gm} for five minutes or 0.0140^{gm}, making a total of 0.0236^{gm}. Now, $0.1500 - 0.0236 = 0.1264$; it is thus seen that the two methods check within 0.004^{gm} for a one hour's run.

It would be useless to give the details of the other two check experiments, since they were carried on in exactly the same manner and extended through approximately the same length of time. It will suffice simply to show the results of the three experiments, corrected for time, as follows:

TABLE IV

	Transpiration as recorded by potometer	Transpiration as shown by P_2O_5 tubes	Difference
1st experiment.....	0.1264^{gm}	0.1260^{gm}	0.0004^{gm}
2nd experiment.....	0.0690	0.0660	0.0030
3rd experiment	0.0614	0.0624	0.0011

It will be noted again from Table II that the transpiration rate was greatly reduced during the time the plant was in the cylinder. This was of course due to the increase in relative humidity in the air, owing to the transpiration from the leaves. It may be suggested, therefore, that the plant was thus shown to be under abnormal conditions. However, the normal air in the room was at a temperature of 27° C. and contained 10.9^{mg} water per liter. According to the Smithsonian tables, such air at saturation contains 25.4^{mg} per liter; the relative humidity of the normal air was therefore 42.5 per cent. Since 19.5 liters of air were drawn through the transpiration cylinder, from which the P_2O_5 collected 343^{mg} of water, the air in the cylinder contained 17.5^{mg} per liter. This would give a relative humidity of 68.8 per cent. The change in relative humidity from the outside air to that inside the cylinder was thus seen to be from 42.5 per cent. to 68.8 per cent. This cannot be termed abnormal, since much greater changes in the outside air take place from day to day, and the range in a given day is very often even wider. Since the air was completely changed in the cylinder every thirty-six seconds, this condition of humidity must have been reached during that time, and have remained constant for the remainder of the hour. Owing to changes in temperature and light a plant in the open will vary much more in the transpiration rate in the course of a few hours than did the alfalfa plant when placed inside the cylinder. Until the exact effect of light, humidity, and temperature are known, therefore, and reduced to formulae whereby, the conditions of the given transpiration experiment being known, the transpiration constant for that plant can be estimated, all comparative transpiration experiments must be made at the same time, and under conditions as nearly identical as possible. The results of such experiments are moreover valuable only in proportion to the degree in which identical conditions are approached.

In order to test the practicability of this method in the field, I selected two alfalfa plants, growing within about 12^{dm} of each other, which showed marked differences in form and texture of the leaves. They had been previously cut at the same time and the stems were therefore of the same age and stage of growth, that is, just beginning to bloom. Three simultaneous comparative experiments were made on these two plants, in order to ascertain whether any constant

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difference could be shown to exist in their transpiration rates per sq. cm. of leaf surface. The following table gives the details of this work. The column marked "check" contains the data derived from the apparatus set up to measure the quantity of water in the normal air.

An examination of Table V shows a constantly higher rate for no. 64 over that of no. 67; the rate of difference, however, was very variable. Unfortunately a larger leaf area was taken each time for no. 67, so much so that the relative humidity in its cylinder was higher than that of no. 64 in the first two experiments. This fact would place no. 67 at a disadvantage in these two experiments, since the higher relative humidity would retard to a greater degree its transpiration rate. Had it not been for the third experiment, therefore, in which, notwithstanding the greater leaf area of no. 67, the total transpiration of no. 64 was greater, thereby causing a higher relative humidity within its cylinder, the series would have been inconclusive. This third experiment, however, confirms the results of the other two, by showing that plant no. 64 may even overcome the disadvantage of a higher relative humidity and still transpire nearly twice as much per sq. cm. of leaf surface as the other.

It may be well to add here several suggestive details for those who wish to use this method. On account of the strong affinity of P_2O_5 for water, it must be kept very tightly sealed. Moreover, it is a difficult substance to handle, especially to transfer to the mouth of a small U-tube. I have found it very convenient to keep it in such a flask as is made especially for holding anhydrous copper oxid. This has a small neck out of which the P_2O_5 can readily be poured into the test tube, is fitted with a good ground-glass stopper within, and a ground-glass cap without. I have found that phosphorus pentoxid keeps perfectly dry in this form of bottle; the stopper does not stick fast, and it is ready for use at any time.

In filling the U-tubes it is well to push a bit of glass wool into the tube with a glass rod, pour on this about 0.5^{gm} of P_2O_5, then more wool and more P_2O_5, until the tube is filled. A bunch of glass wool is put on the top, so that in handling the tubes the P_2O_5 will not get into and clog the intake and outflow tubes while they are being handled, between the times of weighing and setting up the apparatus.

TABLE V

FIRST EXPERIMENT

Plant no.	Date September	Experiment began	Experiment ended	Total gain in P_2O_5 tubes: mg.	Amount of air used: liters	Mg. of water in air used	Net gain of P_2O_5 tubes: mg.	Time: duration of experim't in minutes	Total number of leaves	Total area of leaves: sq. cm.	Loss mg. per hour per sq. cm. leaf surface	Relative humidity of air in cylinder	Relative humidity of external air	Temperature inside of cylinder	Temperature of external air
		P. M.	P. M.									%	%		
64.....	21	3:50	4:50	375	19.5	130	245	60	33	22.282	10.9	77.5	28.7	26°5 C.	25° C.
67.....	21	3:51	4:55	418	19.5	130	288	64	14	32.457	8.3	86.4	28.7	26°5 C.	25 C.
Check.....	21	3:48	4:51	130	19.5	....	....	63	....	.....	....	....	....	.....	.....

SECOND EXPERIMENT

		A. M.	A. M.												
64.....	23	10:16	11:26	324	19.5	148	175	70	12	17.130	8.7	59.8	28.	28°5 C.	28 C.
67.....	23	10:22	11:29	353	19.5	148	205	67	14	41.981	4.3	65.3	28.	28°5 C.	28 C.
Check.....	23	10:14	11:15	148	19.5	....	....	61	....	.....	....	....	....	.....	....

THIRD EXPERIMENT

		P. M.	P. M.												
64.....	23	4:13	5:29	422	19.5	126	295	77	29	21.252	10.9	80.4	25.3	28 C.	27° C.
67.....	23	4:16	5:40	415	19.5	126	289	84	11	33.810	6.1	79.1	25.3	28 C.	27° C.
Check.....	23	4:10	5:14	126	19.5	....	....	68	....	.....	....	....	....	.....	.....

It is advisable to have a number of tubes already filled where work is being done in the field, in order that several parallel experiments may be run before returning to the laboratory for making weighings. The same tube may be used repeatedly so long as there is a part of it filled with dry P_2O_5. Care should be taken, however, to set up the tube in the same way each time, that is, to have the air enter and pass out of the tube in the same direction. The reason for this is that the phosphoric acid, after being formed from P_2O_5 plus water, will itself take up water. If now the tube be turned so that perfectly dry air in leaving the tube passes over the phosphoric acid, which has previously taken up an excess of water, it will itself take up water from the acid and the tube will lose weight.

It requires some experience to know how much leaf area to include in the cylinder for each experiment. After a few trials, however, one will learn to estimate sufficiently closely the capacity of the apparatus so as not to overcrowd it. Overfilling is indicated by the collection of moisture drops on the side of the cylinder, showing that the air inside has reached the saturation point. This may be remedied either by reducing the amount of leaf surface inclosed, or by increasing the rate of flow of the water through the aspirator.

This method of measuring transpiration may be said to be only a modification and a new adaptation of the methods used by LAMARLIÈRE[1] and E. and J. VERSCHAFFELT,[2] in that air is drawn over the plant in the same manner, and the transpired moisture collected in U-tubes containing hygroscopic substances which are not contained in the vessel with the plant, but are connected in the same aspirating series, so that the air, after passing through the evaporation cylinder, next passes through the U-tubes. However, a different absorbent is used and the apparatus, moreover, is adapted for measuring the transpiration of plants on their own roots. The essential point of difference, nevertheless, lies in the condition of the air as supplied to

[1] GANEAU DE LAMARLIÈRE, L., Recherches physiologiques sur les feuilles, developpées à l'ombre et au soleil. VI. Transpiration. Rev. Gén. Botanique **4**:529. 1892.

[2] VERSCHAFFELT, E. en J., De transpiratie der planten in koolzuurorije lucht. Botanisch Jaarboek (uitgegeven door het kruidkundig genootschap "Dodonaea" te Gent) **2**:305. 1890.

the plant. While in my method normal air is supplied, both of the above investigators first completely dried the air before allowing it to reach the plant. This is detrimental, for as BURGERSTEIN[3] says: "In Gegensatze zur zweiten hat die dritte Methode, bei welcher die evaporierte Wassermenge aus der Gewichtszunahme hygroskopische Substanzen in Erfahrung gebracht wird, den Nachteil das sich die Pflanze in einer zu trockenen Luft befindet."

SUMMARY

1. In plant breeding and in physiological and ecological work, it is very necessary to have some accurate and practical method of measuring the transpiration of plants.

2. The potometer method does not give the normal transpiration rate of a plant, neither can it be depended upon to give a rate which is even comparative as between different plants.

3. By the method herein described the transpiration of a plant under known and constant conditions may be accurately measured.

4. It is possible by this method to demonstrate individual differences in the transpiration rates in different plants of the same species.

5. By the use of this apparatus, data may be secured to serve as a basis for plant selection and breeding.

MANHATTAN, KANSAS

3 BURGERSTEIN, ALFRED, Die Transpiration der Pflanzen 12. 1904.

THE TOXIC PROPERTY OF BOG WATER AND BOG SOIL

ALFRED DACHNOWSKI

(WITH SIX FIGURES)

The publication of recent work on the existence of injurious substances excreted from roots of plants (**19, 12, 16,**) has necessarily resulted in disclosing to ecologists some overlooked data. Repeatedly it has been shown that the commonly accepted environmental factors are not always sufficient to explain certain important problems of association among plants. It must be admitted, therefore, that there is a problem to be solved not only regarding the relation of one field crop to another, but also with reference to the succession of one plant society by another.

In the study of the structural adaptations of bog plants and the causes of their occurrence in bog areas, various theories have been brought forward. The idea generally current among workers in the ecology of bogs is that the geographical distribution of bogs and the local differences in the flora of bog areas and swamps have probably come about chiefly through post-glacial migrations and changes in the physiography of the habitat. The cause determining the structural characteristics of bog plants is generally understood to lie in the "physiological dryness" of the habitat. But while some writers lay stress upon low temperature of the bog substratum and the presence of drying winds as the prominent factors (**11, 7, 8**), others emphasize humous acids in the soil, abundance of soluble salts, and alkalies (**15**). More recently the effect has been correlated with low temperature and lack of aeration of the subsoil rather than with acidity (**6, 17**).

In 1904, while at work on the ecology of ravines near Ann Arbor, Mich., the writer became convinced that the reactions of plants on their habitat were equally as great and profound, in some cases, as the influence of edaphic and climatic factors. In various places the decomposed remains of an earlier vegetation led to mechanical and chemical changes in the soil, the extent of which was more effective

toward breaking up the flora into a heterogeneous formation, accompanied by a frequent replacement of one dominant group by another (3). These reactions of plants seemed still more pronounced in bog societies. During the past year a grant obtained from the Emerson McMillin Research Fund afforded an opportunity to test by physiological methods the nature of plant reactions. The investigation here reported forms a part of a more extended study on the ecology of Buckeye Lake. This brief report is merely intended to reveal the toxic character of bog water and bog soil. A more detailed account, together with data obtained from an inquiry on the possible isolation and identification of the toxic bodies by a method of fractional distillation, will appear later.

Buckeye Lake is situated 40^{km} east of Columbus, Ohio, in a region free from limestone. It is an extensive body of water about 16^{km} long and 1.6^{km} wide, and was formerly known as the Licking reservoir. The reservoir was originally a lake in the glacial drift. Its chief supply today is the south branch of the Licking River. In 1883 and again in 1834 its water surface was raised by forming a dike around the west end. Near the northern bank, and midway between the small towns of Lakeside and Avondale, is a bog island, approximately one-tenth the dimensions of the lake. Soundings which were made to determine the character of the peat gave $9–12^{m}$ as the depth of the island. With its surface vegetation of distinctly northern forms, the island is virtually a water culture on a large scale. The plants are not dependent for any important part of their food on the soil; rooting in the soil at such depth is not possible here. The vegetation presents two well-marked zones: a central one consisting of sphagnum, several species of Carex, Menyanthes trifoliata, Dulichium arundinaceum, Scheuchzeria palustris, Eriophorum, Oxyzoccus, Drosera, Rhus vernix, Aronia nigra, and others; and a marginal zone which includes besides various forms of Salix, Alnus incana, A. rugosa, Ilex verticillata, Cornus canadensis, etc., a few small oaks, and Acer rubrum as the dominant form. Mycorhiza is quite common in both zones. Many plants are strictly hydrophilous, and such plants of the cultivated variety as are grown in either zone for experimental purposes show marked difficulties of absorption, soon become stunted,

and often take on xerophilous characters. In the following account these zones are spoken of as the *central zone* and the *maple-alder zone* respectively. The bog water and bog soil used in the experiments were brought every month to the laboratory in glazed earthen-ware jugs from stations which remained identical throughout the period of investigation.

To ascertain the osmotic pressure of the bog water, determinations of the freezing-point were made. As compared with the freezing-point of pure distilled water the average lowering in the various determinations is 0°.007 and 0°.009 for the central station and the maple-alder station respectively. Compared with similar determinations for Michigan bogs (**13**) the bog water of Buckeye Lake has no higher concentration.

Data on temperature deviations in the bog substratum are omitted here as having no particular significance in the problem at hand in this region. They do not seem adequate to account for the differences, since plants growing in soil, nutrient solutions, or bog water are equally affected. If there is any property of bog water which prevents rapid and successful invasion of plants, this inhibiting influence must rest not in the physical character of the habitat alone, but in some chemical quality as well.

A study of the acidity of the bog water under examination gave results differing but little from those obtained in the Michigan bogs (**13**). Titrations were made with a $n/100$ KOH solution. The bog water from both zones is alkaline to methyl orange and acid to phenolphthalein. A comparison of the acidity figures shows that the bog water of the central station is uniformly less acid than that of the maple-alder zone. Boiling, however, greatly reduces the acidity of the bog water in the latter station. This is due to the escape of carbonic acid. In the light of the results here brought out, the presence of the toxic bodies is not necessarily to be correlated with high acidity.

To determine the presence and possible nature of the injurious substances affecting plants through their toxic effects, the following experiments were planned. Familiarity with the behavior and the conditions of development of *Marchantia polymorpha* (**4**) suggested marchantia gemmae of known history as an indicator for preliminary observations. A large number of gemmae were placed in crystallizing

dishes (9.5×4^{cm}) containing 100^{cc} of bog water. Cultures were prepared, containing respectively the untreated bog water from each zone and spring water. The gemmae were allowed to float on the surface of the solutions. An additional series of test conditions was arranged at the same time from the bog water of each zone variously treated. In the table given below, culture medium no. 3 is bog water aerated daily by means of a rubber bulb; no. 4 is prepared by mixing with the bog water dry calcium carbonate and then filtering off the solution; no. 5 is treated by shaking the bog water with carbon (lampblack) and then filtering off the solution; no. 6 is a culture medium obtained by growing in distilled water in battery jars a set of representative plants from each zone. The attempt is made here to simulate undrained bog conditions and to test the water for excretions of roots. To discover whether the effects of poisons were also manifest in the bog substratum, a relatively concentrated aqueous extract was prepared. Quantities of the subsoil from each station were taken from a layer 30^{cm} below the surface vegetation and dried in an oven at a temperature varying between 52° and 60° C. One gram of the material was then mixed with 100^{cc} of distilled water and left standing for several days. The soil solution thus obtained was used as culture medium no. 1. There were thus produced six conditions for each zone in which it was possible to test the bog soils, the excretions of bog plants, the effect of aeration, and toxic ingredients of bog water. The following Table I shows the results of growth in length of marchantia gemmae during a period of twelve and twenty-five days.

It will be noticed that the gemmae made scarcely any growth in the bog soil solution, while in the untreated bog water a fairly good growth occurred. An inhibiting action of these solutions is plainly marked. Evidence of this is further obtained from a microscopic study. For the first five or six days the gemmae made some growth, but after ten days development ceased. Only in the untreated bog water the two opposite growing points of the gemmae were thrifty in appearance. They gradually gave rise to narrow threadlike filaments, which at the end of the twentieth day began to broaden at the tip. In all solutions growth was greatly increased after treatment. Exceptions were noted only when the bog water used was collected just following

TABLE I

MARCHANTIA POLYMORPHA

Culture solution	Growth in 12 days Length in mm.	Growth in 25 days Length in mm.	Remarks
I. Central zone:			
1. Bog soil extract	1 and less	.....	dead after 8 days
2. Bog water untreated	1 –1.5	1.5– 2	filamentous outgrowths
3. Bog water aerated	4 –6	6 – 8	
4. Bog water neutral	5 –5.5	6 – 7.5	
5. Bog water filtered	7.5–8	11 –12	
6. Bog plant water	2	5	
7. Spring water	3 –4	4 – 5	
II. Maple-alder zone:			
1. Bog soil extract	1	1 – 2	larger number dead after 12 days
2. Bog water untreated	6 –7.5	11	
3. Bog water aerated	6 –8	12	
4. Bog water neutral	6	10.5–14	
5. Bog water filtered	5 –8	10 –11	
6. Bog plant water	5 –6	10 –12	

a period of heavy rains, or when the vessels containing the bog water were left uncorked. The differences in growth in the various solutions were less marked, showing that the degree of toxicity at one concentration was entirely different at another. The same is to be said of solution no. 6; its toxic character became more marked with increase in the time during which the bog plants were under cultivation.

Briefly summarized, the data thus far agree in showing (1) that the contrasts in the relative growth of plants in solutions from the maple-alder zone were less marked than those in the solutions from the central zone; (2) that the inhibiting factors of bog conditions are in part due to the presence of injurious water-soluble substances; (3) that the central zone possesses these toxic bodies more decidedly than the maple-alder zone; and (4) that in both zones the toxicity can be corrected by a method of aeration and by the use of calcium carbonate and carbon black.

A series of experiments was next made in the form of bog water cultures with various cultivated plants. Half-liter glass jars of the Mason pattern were used, and prepared in the conventional way. The seeds were germinated in sawdust. Germination in quartz sand and in paraffin-coated disks of galvanized iron wire was found less satisfactory. Transplanting was done when the plants had

attained a height of 5–6^{cm}. The culture media used were prepared as indicated for marchantia. From two to six plants were used for 400^{cc} of solution. Each experiment was continued for 7 to 10 days according to the amount of water transpired before renewing the

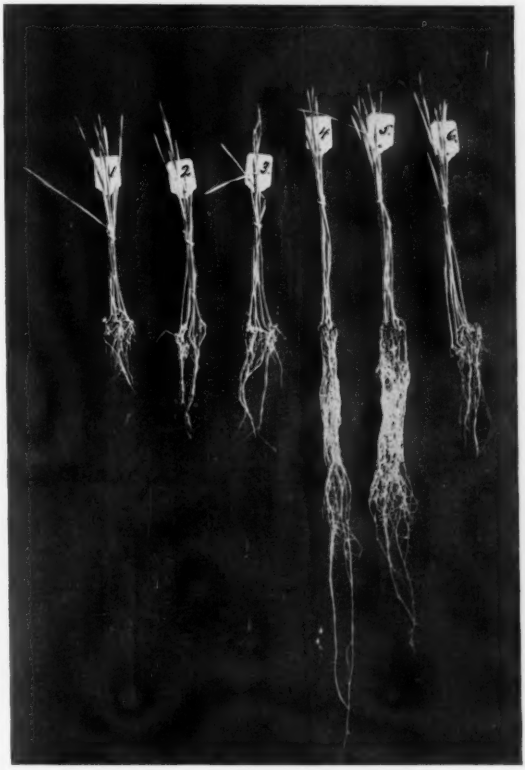

FIG. 1.—Wheat plants from various cultures of bog water and bog soil. Numbers as in the text, p. 133. Six plants from each solution.

culture solution. The different cultures always stood side by side in the university greenhouse, so as to give uniform environment. The light conditions were the same also; direct sunlight was avoided by cloth screens. In place of temperature and moisture readings, measurements of the evaporation power of the air were obtained from

the records of two atmometers. The instruments were prepared on a scale as given by LIVINGSTON (**14**). The integration of humidity, temperature, and air-current data given in a weekly rate varied between 200 and 270^{cc}.

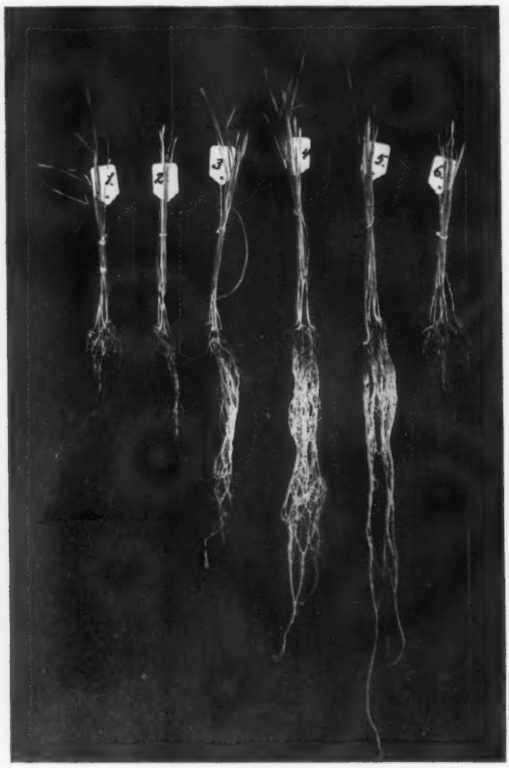

FIG. 2.—Wheat plants from various cultures of bog water and bog soil. Numbers as in the text, p. 133. Six plants from each solution.

As an aid for comparing the rate of growth of similar plants in different media various criteria were used. The main emphasis, however, is placed upon the total transpiration for a definite period of growth, since the difference between the amounts of water lost has been shown to be equivalent to the difference between the physiological

value of the solutions (**19**). Other criteria employed were the condition of the roots, green and dry weight of plants, length and anatomical structure of roots, stem, and leaves. None of these alone can be regarded as accurate measures of plant activity, but taken together they generally agree in indicating the relative value of the results. Without dwelling here at length upon the exact data derived from these experiments, only the results in transpiration-increase are given below in tabular form. The percentage increase in transpiration is calculated for the larger number of the plants upon the basis of the quantities for the bog soil solution considering it as unity.

TABLE II

PERCENTAGE INCREASE IN TRANSPIRATION

Culture solution	Wheat	Corn	Phaseolus	*Vicia faba*	Elm	Buckeye	Cowpea	Oats	Tradescantia
I. Central zone:									
1. Bog soil extract*.....	0	0	0	0	0				0
2. Bog water untreated...	19	16	113	22	68	0	0		9.8
3. Bog water aerated.....	55	27	201	...	...	1.3	20		...
4. Bog water neutral.....	209	91	...	100	...	...	...		8.6
5. Bog water filtered.....	245	52	225	215	94	38.8	42		24.7
6. Bog plant water.....	54	22	184	...	...	...			
II. Maple-alder zone:									
1. Bog soil extract*.....	0	0	0					0	
2. Bog water untreated...	38	65	287					90	
3. Bog water aerated.....	164	71	....					44	
4. Bog water neutral.....	298	136	335					148	
5. Bog water filtered.....	256	76	...					...	
6. Bog plant water.....	11	40	178					113	

*4^{gm} of bog soil and 400^{cc} distilled water.

An increase in the dry weight of roots and tops was obtained in all plants growing in the solutions treated with $CaCO_3$ and carbon black. For the corn and wheat respectively the increase in the dry matter produced varied from 20 per cent. to 50 per cent. during the time of the experiment.

It will be observed that the evidence derived from wheat, corn, bean, elm, and buckeye seedlings (two years old), and other plants yields results and conclusions similar to those pointed out for marchantia. The plants grown in the bog soil extract and in the untreated bog water show stunting clearly in the roots. The tops of the plants are more nearly alike, except in the stronger solutions. Marked

differences in the degree of sensitiveness to toxicity or of the oxidizing power of roots are noticeable for the various plants. Phaseolus and *Vicia faba* proved thus far to be the most plastic plants. In the solutions filtered with $CaCO_3$ and carbon black the tops surpass in

FIG. 3.—Corn plants from the various cultures of bog water and bog soil. Numbers as in the text, p. 133. Four plants from each solution.

development the growth of roots. The plants show marked variations in the internal structure of leaf and stem. Those grown in the bog soil extracts show distinct xerophilous characters. The leaves are reduced in area, thicker, of a deeper green, and with revolute

margins; responses which cannot be attributed to light but to a reduced transpiration current (**18**) consequent upon the toxicity of the habitat (*figs. 1–6*).

It is worthy of note in this connection that when grown in a 0.01

FIG. 4.—Corn plants from the various cultures of bog water and bog soil. Numbers as in the text, p. 133. Four plants from each solution.

per cent. solution of strychnin sulfate, atropin sulfate, or other toxic body of a similar nature and with a high reducing power, the same dwarfing effects are obtained with Phaseolus. When treated with $CaCO_3$ and carbon black the solutions become highly beneficial. The accelerated growth and transpiration are no doubt due to the

presence of these substances in small amounts, and the behavior of the plants is very much like those grown in a 0.0001 per cent. solution of strychnin or atropin sulfate.

The striking agreement of results obtained from such a variety of material seems sufficient proof that the factors inhibiting plant growth and plant association and succession are at least in part due to the plants themselves. Carbon black and calcium carbonate add no soluble matter to the solutions (**2**), hence it becomes certain

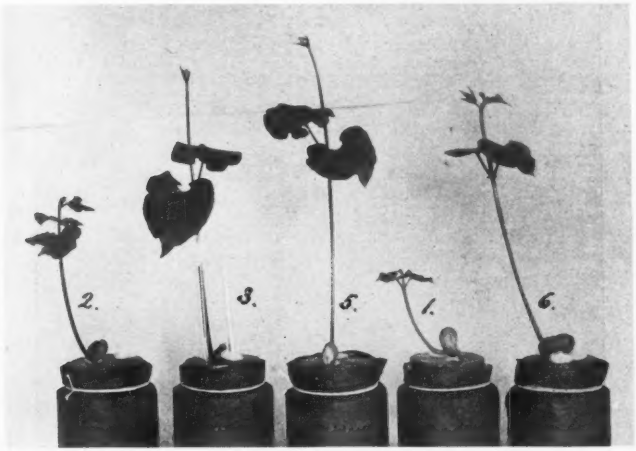

FIG. 5.—Average plants of *Phaseolus multiflorus*, showing effect of bog water variously treated. Numbers as in the text, p. 133.

that the beneficial effects cannot be due to the introduction of nutrient material but to the taking up, i. e., the adsorption of injurious substances present. This would indicate, therefore, that the changes in the soil conditions are produced by noxious substances formed in the absence of O_2. They may be products of decomposition, perhaps they are in part plant excreta, but whatever their nature, they are water-soluble toxic bodies which retard oxidation in the tissues and decrease transpiration, thus causing xerophily, stunting, and even death.

It may be readily questioned whether part of the response arises from a deficiency of oxygen in the soil. The evidence obtained by

BENNETT (1) is against aerotropism in roots. It follows, therefore, that results reported as due to lack of aeration in the bog substratum are really due to toxicity. Under natural conditions the inhibiting effect is eliminated by aeration, a slow process of oxidation preventing the accumulation of injurious plant excreta in the

FIG. 6.—*Vicia faba* from cultures of the central zone. Numbers as in text, p. 133. Transpiration data and photograph by Miss FREDA DETMERS.

soil. However, on account of the great demand for oxygen, the process can be carried on efficiently only near the surface. Beneath, the active bodies are more plentiful in the dead material than in the plants themselves. An undrained peat substratum, therefore, must necessarily cause more marked deterioration in development and permit a different association and succession of plants than a drained habitat.

That the response to toxic bodies when present in small amounts may lead to acceleration of growth has become evident also in connection with a biometric study on the annual wood-increment in *Acer rubrum* (**5**). Measurements upon such trees from the outermost edge of the maple-alder zone as were nearly the same in size, age, concentric growth of wood, and general environment, as similar forms found in woodlots near the shore gave the following differences in the frequencies of rings:

Width of rings in mm	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5
Frequencies in bog-habitat	16	10	23	20	27	12	20	5	7	5
Frequencies in woodlots	26	30	31	9	6					

Width of rings in mm	6	6.5	7	7.5	8	8.5	9	9.5	10
Frequencies in bog-habitat	5	5	6	1	2	0	1	0	2
Frequencies in woodlots									

The mode and the variation constants derived from them are equally interesting:

Habitat	Bog	Woodlots
Mode	3 mm	2 mm
Mean	3.425 ± 0.098	1.701 ± 0.038
Standard deviation	1.870 ± 0.069	0.566 ± 0.027
Coefficient of variability	54.60 ± 2.55	33.28 ± 2.46

We have here the type and the place-habit from two distinct edaphic conditions. The differences in the soil habitat have led to physiological variations which changed not only the type, but the variability and even the sign of the skewness. Quantity and quality of the wood have been affected; as products of the environment they are a measure of environmental conditions.

To attempt to correlate the data with the work of previous authors on toxic action is obviously impossible. Definite knowledge of the chemistry of bog water and bog soils is lacking at present. There are always present a great variety of chemical and biological agents, and products of decomposition, which may react collectively. Hence definite conclusions cannot be based upon the results obtained here. The limited extent to which these experiments have been carried, gives no more than a suggestion of the possibilities.

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LITERATURE CITED

1. BENNETT, M. E., Are roots aerotropic? BOT. GAZETTE **37**:241. 1904.
2. BREZEALE, J. F., Effect of certain solids upon the growth of seedlings in water cultures. BOT. GAZETTE **41**:54. 1906.
3. DACHNOWSKI, A., Contribution to the botanical survey of the Huron River valley. Mich. Acad. Sci. Report **9**:116. 1905.
4. ———, Zur Kenntnis der Entwicklungs-Physiologie von *Marchantia polymorpha*. Jahrb. Wiss. Bot. **44**:251–286. 1907.
5. ———, Type and variability in the annual wood-increment of *Acer rubrum*. Ohio Naturalist **8**:343. 1908.
6. FRÜH, J., and SCHRÖTER, C., Die Moore der Schweiz mit Berücksichtigung der gesammten Moorfrage. Geol. Komm. d. Schweiz. naturf. Gesells. Bern. 1904.
7. GANONG, W. F., Raised peat bogs in New Brunswick. BOT. GAZETTE **16**:123. 1897.
8. ———, Raised peat bogs in the province of New Brunswick. Proc. Roy. Soc. Can. II. **3**:131. 1897.
9. JENSEN, G. H., Toxic limits and stimulation effects of some salts and poisons on wheat. BOT. GAZETTE **43**:11. 1907.
10. ———, Some mutual effects of tree roots and grasses upon soils. Science N. S. **25**:871. 1907.
11. KIHLMAN, A. O., Pflanzenbiologische Studien aus russisch Lappland. Act. Soc. Fauna Flora Fenn. **6**:113. 1890.
12. LIVINGSTON, B. E., Studies on the properties of an unproductive soil. U. S. Dept. of Agr., Bureau of Soils, Bull. 28. 1905.
13. ———, Physiological properties of bog-water. BOT. GAZETTE **39**:348. 1905.
14. ———, The relation of desert plants to soil moisture and to evaporation. Carnegie Institution of Washington, Publication **50**:20. 1906.
15. SCHIMPER, A. F. W., Pflanzengeographie auf physiologischer Grundlage. Gustav Fischer, Jena. 1898.
16. SCHREINER, O., and REED, H. S., The production of deleterious excretions by roots. Bull. Torr. Bot. Club **34**:279. 1907.
17. TRANSEAU, E. N., The bogs and the bog flora of the Huron River valley. BOT. GAZETTE **41**:38. 1906.
18. ———, The development of palisade tissue and resinous deposits in leaves. Science N. S. **19**:866. 1904.
19. WHITNEY, M. and CAMERON, F. K., The chemistry of the soil as related to crop production. U. S. Dept. Agr., Bureau of Soils, Bull. 23. 1903.

BRIEFER ARTICLES

THE FLOWERS OF WASHINGTONIA

(WITH FIVE FIGURES)

While my paper on the genus Washingtonia[1] was passing through the press, I had the pleasure of receiving from Dr. BECCARI a copy of his recent monograph of the Coryphine palms of America.[2] In his treatment of Washingtonia this distinguished palmographer gives much weight to certain floral characters which have been heretofore overlooked, and it seems desirable that these should be brought to the attention of American botanists, in order that their value may be tested by field studies.

These distinctions relate to the characters of the filaments, the stigma, and the summit of the ovary. In the flowers of Washingtonia the filaments of the stamens opposite the lobes of the petals are consolidated with them for nearly one-third their length, and are much thicker than the free filaments opposite the sinuses.

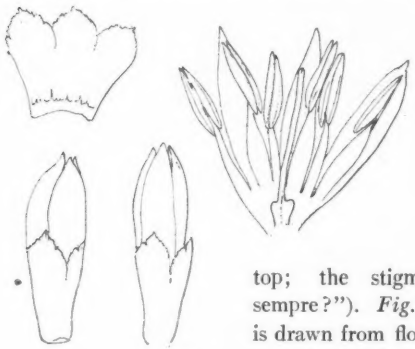

FIG. 1.—*W. filifera* Wendl., Botanical Garden, Palermo, August, 1906.—O. BECCARI. ×3.5.

Washingtonia filifera Wendl. is defined as having the lobal filaments thickened-fusiform; the ovary turbinate, 3-lobed, and strongly gibbous at top; the stigma undivided ("puntiforme, sempre?"). *Fig. 1* represents this species, and is drawn from flowers of a tree growing in the Botanical Garden at Palermo, Italy.

Its variety *microsperma* Beccari differs in its slightly less strongly fusiform lobal filaments, but mostly in its somewhat smaller flowers and decidedly smaller seeds. *Fig. 2* shows the variety, drawn from flowers of a tree in the Garden Ricasoli, Port Ercole, Tuscany.

[1] PARISH, S. B., A contribution toward a knowledge of the genus Washingtonia. BOT. GAZETTE **44**:408–434. *figs. 12.* Dec. 1907. I take this opportunity to correct two errors: Page 409, line 18, for "eleven" read "fifteen;" page 415, line 3 from bottom, for "the trees" read "most of the trees."

[2] BECCARI, ODOARDO Le Palme Americane della tribú Corypheae. Estratto dalla Webbia **2**:pp. 343. Oct. 1907. Firenze.

The rank of species and variety seems here assigned somewhat arbitrarily, and it may be of interest to give the history of the trees which have been taken as their respective types. The palm accepted as typical *W. filifera* is a certain tree in the Garabaldi Garden, at Palermo, Italy, which was raised from seed at the Botanical Garden in the same city, in 1874, and which began to flower in 1892. The source of the seed is not known.

Five or six living plants of the *Prichardia filifera* of his trade catalogue were exhibited by LINDEN at the international exhibition at Florence, in May, 1873. Three of these exhibition plants are now large trees, producing flowers and fruit, and these are taken by BECCARI as the types of his *W. filifera microsperma*. As these palms are directly traced to LINDEN, and were exhibited by him as *Prichardia filifera*, it would seem probable that they are about as near as we are likely to get to authentic representatives of WENDLAND'S first published species.

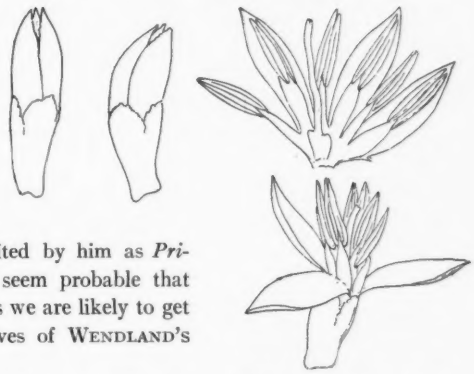

FIG. 2.—*W. filifera microsperma* Becc., Garden Ricasoli, Port Ercole, Tuscany, August, 1906.—O. BECCARI. ×3.5.

The flowers of *W. robusta* Wendl. are described as having the lobal filaments tuberculately enlarged at the coherent base, and abruptly subulate above; stigma bilabiately 3-parted into three short lobes; ovary turbinate at summit, but neither excavated nor gibbous. On these grounds BECCARI sustains the specific rank of this palm; and should they prove constant, it may be desirable to follow this disposition. *Fig. 3* is from a flower of a tree in the Botanical Garden at Palermo. Its historical identification with the Wendlandian plants is not related. The first two characters hold in the flowers of Californian trees which have been referred here, so far as concerns the few specimens I have examined. The ovarian character is less satisfactory.

W. gracilis Parish has flowers very near those of the last, except that the summit of the turbinate ovary is very distinctly 3-lobulate. *Fig. 4* was drawn from a flower taken from Mr. MCLEOD'S tree, a panicle of which is the subject of *fig. 10* of my previous paper. BECCARI regards this palm as a variety of *W. robusta*. It would be possible, although in my opinion

undesirable, to regard all the Washingtonias as varieties of a single polymorphous species, but the one now under consideration would of all be the least capable of such comprehension. Without question floral characters

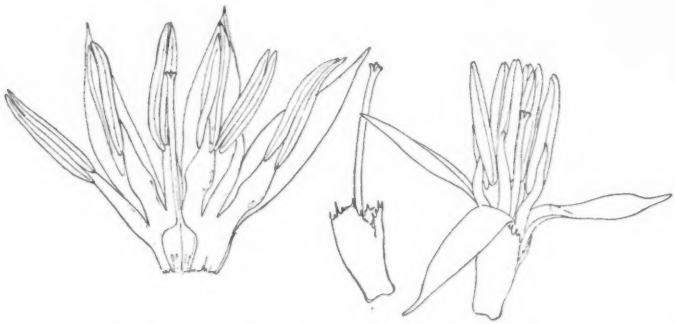

FIG. 3.—*W. robusta* Wendl., Botanical Garden, Palermo, August, 1906.—O. BECCARI. ×3.5.

are of greater diagnostic value than those drawn from foliage or habit; but when the latter are of marked distinction, and apparently constant, they cannot be refused great weight.

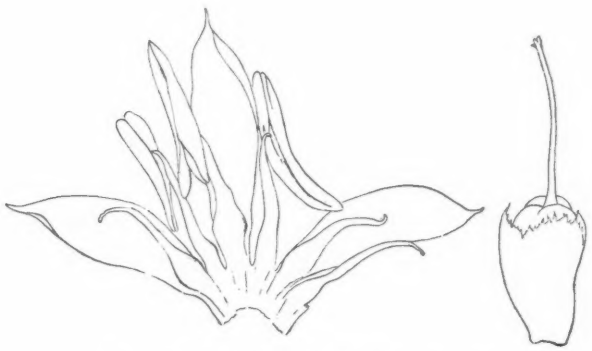

FIG. 4.—*W. gracilis* Parish, Riverside, Cal. ×5.

BECCARI had not had an opportunity of examining flowers of *W. sonorae* S. Watson, and he regards it as a doubtful species, which may be a variety of *W. robusta*, suspecting that the obtusely triangular insertion of

the petiole in the leaf blade may not prove a constant character. Through the kindness of Dr. B. L. ROBINSON, of the Gray Herbarium, I have received a few flowers taken from the type specimen of this species, collected by WILLIAM PALMER at Guaymas, Mexico. One of these is represented in *fig. 5*, the anthers being omitted, as all had fallen from the flowers. It will be seen that this has the characters assigned to *W. filifera* so far as the filaments are concerned, the character of *W. robusta* as to the divided tip of the stigma, and the markedly lobate ovary of *W. gracilis*. Such a combination of characters throws a shadow of uncertainty on their value. It

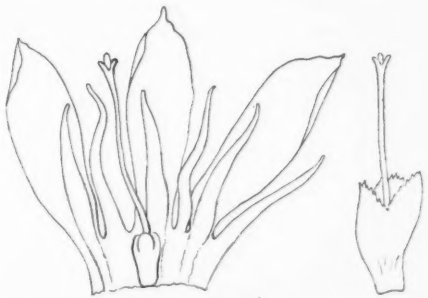

FIG. 5.—*W. sonorae* S. Watson. From PALMER'S type, Guaymas, Mexico. ×5.

must be remembered, however, that they are drawn from a study of too few individuals. What is now desirable is that the proposed characters, both those drawn from the flower and fruit, and from the foliage and habit, should be put to the test by the examination of numerous examples, growing under varying conditions. Especially is it to be hoped that botanists who may have the opportunity should study carefully the groves near Guaymas, and those reported to exist on the seacoast of northern Lower California. Until such extended studies shall be made it cannot be considered that we stand on altogether firm ground in the discrimination of the various indicated species and varieties of Washingtonia.

For the drawings from which *figs. 1*, *2*, and *3* are reproduced I am indebted to the kindness of Dr. BECCARI. They are enlarged seven diameters. *Figs. 4* and *5* are from drawings by Mrs. CHARLOTTE M. WILDER, and are enlarged ten diameters. All the drawings are reduced one-half in the reproduction.—S. B. PARISH, *San Bernardino, California.*

CURRENT LITERATURE

BOOK REVIEWS

The question of sex

The determination and inheritance of sex have presented problems of peculiar interest and also of peculiar difficulty. CORRENS[1] has grappled with them from a new point of view and has gained some surprising results. His point of attack is through the hybridization of plants having different sex characteristics, as for example the crossing of a dioecious species with a hermaphrodite or monoecious species. His most important conclusions are that each germ cell of the forms he has used carries a progamic sex tendency, but that the actual determination of sex is syngamic, that is, it results from the chance that brings together two germ cells having particular sex tendencies. In *Bryonia dioica* he shows that the female germ cells carry always the same sex tendency, namely to produce females; while the male germ cells are of two kinds, half bearing the female tendency and half the male. The male tendency dominates over the female, so that when the eggs are fertilized by these two kinds of sperms, those which receive sperms bearing the female tendency produce females, and those which are fertilized by sperms bearing the male tendency produce males. The females are homozygous (♀+♀) with respect to sex and the males are heterozygous (♀+♂). Evidence is presented that the same condition exists in *Melandrium album*, as shown by crossing with *Silene viscosa*, and he considers it very probable that all dioecious plants are similarly constituted. The author is properly cautious in discussing the applicability of these results to other classes of organisms than those with which he has dealt, and especially to animals, but he discusses WILSON'S noteworthy studies upon the idiochromosomes of the Hemiptera,[2] and points out how readily these can be interpreted on the basis of a sex relation similar to that discovered in higher plants.

An epigamic modification of sex through the influence of nutrition or other external conditions is not deemed to be wholly excluded, owing to the fact that one sex may carry the other in a recessive or latent condition, and it is at least conceivable that such latency may be to some extent modifiable by external factors.

In respect to the sex of hermaphrodite and monoecious plants, it is noted that in all cases of "mosaic" inheritance which have been sufficiently investigated

[1] CORRENS, C., Die Bestimmung und Vererbung des Geschlechtes nach neuen Versuchen mit höheren Pflanzen. pp. 81. *figs.* 9. 1907. Berlin: Gebrüder Borntraeger.

[2] WILSON, E. B., Studies on chromosomes. III. The sexual differences of the chromosome groups in Hemiptera, with some considerations on the determination and inheritance of sex. Jour. Exp. Zool. 3:1. 1906.

there is a distinct factor present for the mosaic condition, so that the sex of such plants is not to be looked upon as due to the presence of the male- and female-producing units alone, but to the presence of a factor determining the tendency to be hermaphrodite or monoecious respectively.

The field for investigation which has thus been thrown open is a very inviting one, and it is to be hoped that other dioecious species which have nearly related hermaphrodite or monoecious species among both plants and animals will be made to yield whatever support they may for the generalizations CORRENS has made.—GEORGE H. SHULL.

Plankton of Illinois River

Four years ago, this journal reviewed the first part (1903) of KOFOID'S *Plankton of the Illinois River*,[3] which dealt with the quantitative investigations and general results. There has just appeared the second part, which deals with the organisms of the plankton and their seasonal distribution.[4] The character of the work, with its mass of statistics, forbids an adequate review. As was stated in the preceding review, this series forms the most important contribution yet made to the subject of river plankton, and the work has been carried on with the most painstaking care. In the discussion of species, plants occupy 45 pages, and animals 230. The plant groups considered are Bacteriaceae, Schizophyceae, Chlorophyceae, Bacillariaceae, Conjugatae, and certain seed plants. Some general conclusions in reference to the seasonal changes are stated, conclusions that are promised detailed discussion in a later paper. For example, each month is characterized by certain plankton features, dependent upon a certain range of hydrographic, thermal, and chemical conditions, and of illumination. There is a certain range of component species, and a range of numbers of individuals, the proportions varying from month to month, and constituting one of the main elements in the seasonal changes of the plankton. Transitions from month to month are most profound at seasons of greatest environmental changes, as at the times of vernal increase and autumnal decline in temperatures. In general two types of plankton were found, the summer and the winter, the vernal and autumnal types being only transitions between the two when organisms from both are present. The winter plankton is characterized by a small number of species peculiar to that season, and a number of perennial forms; the summer by a larger number of summer organisms with the perennial forms.

In reference to the question whether the plankton of streams differs from that of lakes and ponds, the author states that it may be distinguished from them in being a mixed plankton (due to the mingling of planktons from all sources in the

[3] BOT. GAZETTE **37**:472. 1904.

[4] KOFOID, C. A., The plankton of the Illinois River, 1894–1899, with introductory notes upon the hydrography of the Illinois River and its basin. Part II. Constituent organisms and their seasonal distribution. Bull. Ill. State Lab. Nat. Hist. **8**:Article I. pp. vii+360. 1908.

drainage basin), in being subject to extreme fluctuations in quantity and constitution, and in containing no species peculiar to it.—J. M. C.

Floral mechanism

Such is the title of a work whose first part has just appeared.[5] In this part twelve types of common spring flowers are selected, all of which are readily cultivated and may thus be kept under continued observation. In the case of each one of these flowers there is a full account of all the details of structure and the problems presented. A definite scheme of work is elaborated, so that in due order all questions are raised and answered. The work is intended for botanical students, teachers of elementary botany, "lovers of flowers," and candidates for examination.

A single example, selected at random, will illustrate the scheme. Under *Viola odorata* the following topics are presented: history, distribution, nomenclature, description, variations, floral diagram, sectional elevation, development, special mechanism, pollination, cleistogamy, monstrosities, fruit and seed, comparison of allied types, theoretical considerations, and note on Fibonacci phyllotaxis systems. All this is illustrated by five plates, three of them colored.

The large page and handsome type are exceedingly attractive, and the colored plates are as fine as we have seen. In short, the whole appearance of the book is ornate. But still, we wonder at its purpose. The author explains this as follows: "The general idea has been the provision of a methodical framework for the inclusion of all facts of observation and experiment, which may serve as an introductory scheme admitting of progressive elaboration and perfection with the attainment of new information." This sounds as if there was a pedagogical motive; but if it is for the teaching of botany, the tremendous emphasis laid upon a few "type" flowers is something new or something very old; at least it holds no relation to botany as at present developed. If it is a scientific treatise, which the author disclaims, it is too simple and diffuse. If it is for ornament, it is a great success. If it is to give opportunity for the display of admirable printing and three-color work, we have seen nothing better.—J. M. C.

MINOR NOTICES

Kew Index.—The third supplement to this invaluable work has appeared,[6] including names and synonyms of all genera and species from the beginning of 1901 to the end of 1905. The second supplement, which appeared in 1904, and included names through 1900, was under the direction of W. T. THISELTON-

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[5] CHURCH, ARTHUR HARRY, Types of floral mechanism; a selection of diagrams and descriptions of common flowers, arranged as an introduction to the systematic study of angiosperms. I. Types I–XII (Jan. to April). Royal 4to. pp. vii + 211, with 39 colored plates and numerous figs. Oxford: Clarendon Press. 1908. $6.75.

[6] Index Kewensis plantarum phanerogamarum. Supplementum tertium. pp. 193. Oxford: Clarendon Press. 1907. 28*s*.

DYER. The third supplement appears under the direction of D. PRAIN, the new director of the Kew Gardens. The supplement is a record of the remarkable activity in taxonomy during the five years covered, and critical judgment in reference to this great volume of work is becoming increasingly difficult. In fact, the list is a record of publication rather than an expression of opinion. For example, 476 acknowledged species of Crataegus are recorded for the five years, and Rubus is not far behind. To review such a work is impossible. It is only necessary to announce its appearance.—J. M. C.

North American Flora.—The third part of volume 22 has just been issued. It contains Grossulariaceae by F. V. COVILLE and N. L. BRITTON, 43 species (2 new) being referred to Ribes and 40 (4 new) to Grossularia; Platanaceae (6 spp.) by H. A. GLEASON; Crossosomataceae (4 spp., 1 new) by J. H. SMALL; Connaraceae (3 genera, 9 spp.) by N. L. BRITTON; Calycanthaceae (4 spp.) by C. L. POTTER; and the beginning of Rosaceae by P. A. RYDBERG, the key recognizing 18 tribes, 6 of which are completed and the seventh (Potentilleae) begun. Among the 19 genera of Rosaceae presented, Horkeliella (3 spp.) is new; and 29 new species are described, being distributed among Opulaster (4), Spiraea (5), Petrophytum, Aruncus (3), Chamaebatiaria, Lindleyella, Vauquelinia, Sericotheca (6), Horkelia (6), and Ivesia.—J. M. C.

Marine algae of Sweden.—KYLIN[7] has published a monograph of the algal flora of the west coast of Sweden. The species of the four following groups are first presented: Chlorophyceae (12 fams., 26 gen., 71 spp.), Fucoideae (16 fams., 51 gen., 105 spp.), Bangiales (5 gen., 11 spp.), Florideae (16 fams., 55 gen., 107 spp.). One new genus (*Acrothrix*) of Fucoideae is described. The second part of the contribution (80 pp.) presents the ecological factors and analyses the geographical distribution. At the conclusion of the discussion, the 105 species of Fucoideae and the 118 species of Florideae (incl. Bangiales) are distributed into arctic, subarctic, boreal-arctic, cold-boreal, and warm-boreal groups. The paper concludes with "biological" notes, a full bibliography, and an adequate index.—J. M. C.

Das Pflanzenreich.[8]—Part 33 contains the 9 genera of Aloineae (Liliaceae) by A. BERGER, *Chortolirion* being a new genus with 4 species. Altogether, 370 species are presented, many of them with numerous cultivated forms and entering into hybrids. The large genera are Aloe (178 spp., 14 new), Kniphofia (67 spp., 2 new), Haworthia (60 spp.), and Gasteria (43 spp.).

Part 34 contains the Sarraceniaceae by J. M. MACFARLANE, who gives an interesting account (in English) of the structure of the vegetative organs and the

[7] KYLIN, HARALD, Studien über die Algenflora der schwedischen Westküste. pp. 288. *pls.* 7. Upsala. 1907. (Inaugural dissertation.)

[8] ENGLER, A., Das Pflanzenreich. Heft 33, Liliaceae-Asphodeloideae-Aloineae von A. BERGER. pp. 347. *figs. 141* (*817*). *M*17.60. Heft 34, Sarraceniaceae von J. M. MACFARLANE. pp. 39. *figs. 10* (*43*). *M*2.40. Leipzig: Wilhemn Engelmann. 1908.

insect relations of this remarkable family. Heliamphora and Darlingtonia are still recognized as monotypic, but a new species of Sarracenia (*S. Sledgei*, from the Gulf states) is described, 7 in all being recognized.—J. M. C.

Lactarius and Russula.—BATTAILLE[9] has published a monograph of these genera, to which he gives the group name Astérosporés, on account of their echinulate or granulate spores. He describes all of the European species, adding personal observations to the diagnoses of the various authors. The keys are admirably constructed to lead easily to the species. For Lactarius the author has adopted the classification of QUÉLET. For Russula the two grand divisions (Leucosporae and Xanthosporae) of QUÉLET are continued, but a number of subsections are defined and named. At the same time, it is shown, that the color of the spores is not a very reliable character, and the principal groups must be defined by a varying combination of characters.—J. M. C.

Grout's Mosses.—The fourth part of this work,[10] issued in April last, maintains the reputation of its predecessors and brings the author's task within sight of completion. Part V, the final one, is announced for 1909, to contain some plates and text missing from this part, together with an index and other useful adjuncts.

Part IV completes the Leskeaceae and contains a good part of the Hypnaceae, with the usual excellent reproductions of illustrations from the *Bryologia Europaea* and SULLIVANT'S *Icones*, and some characteristic details which are original.—C. R. B.

Index of desmids.—A supplement to NORDSTEDT'S *Index Desmidiacearum*, which was published in 1896, has just appeared.[11] The interval of over ten years has witnessed such an accumulation of material that a large supplement became necessary. The new bibliography included bears testimony to the great activity of the students of the group during this period, about 500 titles being enumerated, under 120 authors. To examine this vast amount of material and to organize it for the purpose of the index has called for an amount of labor that the students of desmids are sure to appreciate.—J. M. C.

Flora of Greece.—The last fascicle of Halácsy's *Conspectus Florae Graecae* was published in 1904, and now a supplement has been issued.[12] The first fas-

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[9] BATAILLE, FRÉDÉRIC, Flore monographique des Astérosporées (Lactaires et Russules). pp. 100. Besançon (route de Vesoul, 18): The author. 1908. *fr.*3.

[10] GROUT, A. J., Mosses with hand lens and microscope. A non-technical handbook of the more common mosses of the northeastern United States. Part IV. Imp. 8vo. pp. 247–318. *pls. 56–75. figs. 134–165.* Brooklyn: The Author, 360 Lenox Road, Flatbush. 1908. $1.25.

[11] NORDSTEDT, C. F. O., Index Desmidiacearum citationibus locupletissimus atque bibliographia. Supplementum. pp. 150. Berlin: Gebrüder Borntraeger. 1908.

[12] HALÁCSY, E. DE, Conspectus Florae Graecae. Supplementum. pp. 132. Leipzig: Wilhelm Engelmann. 1908.

cicle appeared in 1900, so that four to eight years have elapsed since the various parts appeared. During this period the author says that local and visiting botanists have been extremely active in exploration, discovering new stations, plants new to Greece, and new species. All these additions have been brought together in this supplement, so that the *Conspectus* may be regarded as fairly complete again.—J. M. C.

Anatomy of dicotyledons.—The translation of the SOLEREDER'S *Systematische Anatomie der Dicotyledonen*[13] into English gave the author opportunity to revise the work and to add much supplementary matter. This has now been brought together at the instance of the German publisher for the benefit of those who have the original. This large *Erganzungsband* will be desirable for all those libraries that have the first two volumes, for it contains an immense amount of material. Besides the additional data, the concluding remarks have necessarily been revised. —C. R. B.

NOTES FOR STUDENTS

Sieve tubes in Laminariales.—Miss SYKES[14] has investigated the anatomy and histology of Macrocystis and Laminaria, chiefly *M. pyrifera* and *L. saccharina*. A few other species, such as *Sacchariza bulbosa*, *Laminaria digitata*, *Alaria esculenta*, and *Nereocystis Luetkeana*, were also examined to supplement the main results. Chief attention was paid to the morphological nature of the trumpet hyphae and of the true sieve tubes, the presence or absence of protoplasmic connecting threads, the development of sieve plates, and the nature of callus.

Some of the conclusions may be summarized as follows: (1) The trumpet hyphae in *M. pyrifera* and *L. saccharina* are to be looked upon as true sieve tubes. They represent the original central cells of the thallus modified, and may be termed primary pith filaments. Though they differ as to their degree of development, they are certainly homologous with the secondary sieve tubes of Macrocystis, which are similarly derived from the modified primary cortex of the young thallus. (2) It is believed that the histology of the sieve plates in the primary pith filaments and secondary sieve tubes is essentially the same. Threads are formed traversing the young sieve plates, and each gives rise in the older plate, apparently by means of ferment action, to a slime string inclosed in a rod of callus. In Macrocystis each original thread first divides to form a group, and each thread of a group forms its own callus rod, but finally, by fusion, only one slime string is produced from each group. The older sieve plates are obliterated by the deposition of a large mass of callus over their surface, and callus is also formed throughout the length of the old sieve tubes. (3) The callus is to be looked upon as a

[13] SOLEREDER, H., Systematische Anatomie der Dicotyledonen. Ein Handbuch für Laboratorien der wissenschaftlichen und angewandten Botanik. Erganzungsband. Imp. 8vo. pp. viii+422. Stuttgart: Ferdinand Enke. 1908.

[14] SYKES, M. G., Anatomy and histology of *Macrocystis pyrifera* and *Laminaria saccharina*. Annals of Botany **22**:291–325. *pls. 19–21*. 1908.

hydrated form of cellulose, and is found in *L. saccharina* and *L. digitata* in various states of hydration. It appears to be produced in the young sieve plates by the action of a ferment on the already formed cell wall, but is afterward accumulated by deposition from the protoplasm, both on the surface of the sieve plate and on the lateral walls of the tube. (4) The histology of the sieve tubes agrees with that of spermatophytes. The only contrast between the method of obliteration of the sieve tubes in Laminariaceae and Pinus is that in the latter the heads of the slime strings are still visible on the free edge of the callus cushions, and the path of the slime strings can be traced throughout the callus mass; while in Macrocystis and Laminaria the callus is laid down by the protoplasm of the sieve tubes over the heads of the slime strings, so that they are buried by the overlying callus and no perforations can be traced through the rod. (5) The protoplasmic connecting threads throughout the tissue of *M. pyrifera* and *L. saccharina* were demonstrated, but it is impossible to be certain of their formation in case of secondary attachment.—S. YAMANOUCHI.

Primitive angiosperms.—Miss SARGENT has developed more fully her view as to the origin of the monocotyledons,[15] which was stated formally in 1903. The present paper of course deals with the characters of primitive angiosperms, but this is a necessary corollary to the recently developed phylogenetic position of monocotyledons. It is an abstract of a course of eight lectures delivered for the London University about a year ago, and even then leaves the discussion of the origin of the flower to the recent paper by ARBER and PARKIN.[16] It is impossible to discuss the numerous lines of evidence presented and the inferences drawn from them. In general it may be said that facts are treated with a free hand and not always critically, that they are often related to one another with great boldness, and that the conclusions are in some cases more evident than the proofs.

Reasons for believing in the monophyletic origin of angiosperms are first presented, and with the recent development of our knowledge of vascular anatomy, it is questionable whether there exists today any serious objection to this view. And yet, perhaps it is well to have the situation summarized for us.

The reconstruction of the primitive race of angiosperms is based chiefly upon floral structure, stem anatomy, and number of cotyledons. The outcome is a plant with a strobiloid flower (as Magnolia), with a cambium, and with two cotyledons. A comparative study of pteridophytes, gymnosperms, and angiosperms would seem to make the last two conclusions inevitable, and the first at least partially true.

The real contention of the author, however, is the origin of the monocotyledonous condition. There is a very full discussion of all possible alternatives,

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[15] SARGENT, ETHEL, The reconstruction of a race of primitive angiosperms. Annals of Botany **22**:121–186. *figs. 21.* 1908.

[16] ARBER, E. A. N., and PARKIN, J., On the origin of angiosperms. Jour. Linn. Soc. Bot. **38**:29–80. 1907. See BOT. GAZETTE **44**:389. 1907.

and the conclusion reached is that the fusion hypothesis is the most tenable; that is, the two lateral cotyledons of primitive angiosperms have become phylogenetically fused in monocotyledons, and the result appears as a terminal member. The anatomical proofs of this position are fairly well known and seem cogent. The final question asked is as to the cause of fusion, and the answer is, the geophilous habit of the primitive monocotyledons. The author recognizes the fact that there are other distinctive features of monocotyledons which geophily cannot be called upon to explain, but these are "departures from the primitive type."

To boil it all down: the angiosperms are monophyletic; the monocotyledons are derived from the primitive dicotyledonous stock; the terminal "cotyledon" is a historical fusion of two lateral cotyledons, which was induced by geophily; and the other characters of monocotyledons remain to be explained.—J. M. C.

Polar conjugation in angiosperms.—Recently[17] PORSCH attempted to explain the embryo sac and double fertilization in angiosperms. He holds that the two synergids are homologous with the neck canal cells of the gymnosperm archegonium (as to what gymnosperm has two neck canal cells, we are left in doubt); that the oospheres of gymnosperms and angiosperms are homologous; that the upper polar nucleus is homologous with the ventral canal cell of the gymnosperm archegonium; and that the antipodal end of the angiosperm sac is the equivalent of the micropylar end. The triple fusion results from the essentially female character of the polars.

It is with considerable surprise that we find an observer so acute as SCHAFFNER[18] writing that the view of PORSCH in regard to these homologies has much in its favor, and that his interpretation of the triple fusion seems correct. That the eggs of gymnosperms and angiosperms are homologous, no one denies; but the other homologies are so inaccurate that to note them at all seems useless. In following the reduction of the archegonium, one notes in the bryophytes a shortening of the neck and a diminution in the number of neck canal cells. In the lower Filicineae there are two neck canal cells separated by a wall; in the higher Filicineae there is one binucleate neck canal cell, the wall always failing to develop. In the Hydropteridineae even the nuclear division fails to take place and there is only one small, uninucleate neck canal cell; while in the gymnosperms there is no neck canal cell at all. In some gymnosperms there is a ventral canal cell, separated from the egg by a wall; but in more cases there is only a nuclear division without the formation of a wall, and in Torreya even the nuclear division is suppressed. In the Gnetales we note the disappearance of even the archegonium. Recalling such a series, it is difficult to understand how anyone could propose such homologies as those suggested by PORSCH.—CHARLES J. CHAMBERLAIN.

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[17] PORSCH, OTTO, Versuch einer phylogenetischen Erklärung des Embryosackes und der doppelten Befruchtung der Angiospermen. Jena: Gustav Fischer. 1907.

[18] SCHAFFNER, JOHN H., On the origin of polar conjugation in the angiosperms. Ohio Naturalist **8**:255–258. 1908.

Gametophytes and embryo of Cunninghamia.—This monotypic Chino-Japanese genus has been investigated by MIYAKE, who has just published a preliminary notice[19] of his results. The male gametophyte has no prothallial cells, and at pollination it consists of two nuclei (generative and tube). These two nuclei enter the pollen tube, in which the generative nucleus soon divides, one of the daughter nulcei entering into the structure of the rapidly enlarging body cell, and the stalk nucleus remaining free in the cytoplasm of the tube. Pollination occurs early in April, and the tube reaches the archegonial complex about the end of June. There is a solitary megaspore mother cell, which divides about the time of pollination. The embryo sac is invested by a distinct tapetal zone, and before the end of June is full of tissue. The archegonium initials appear early and the development of archegonia is rapid, the complex being fully formed by the end of June. This complex is singular in that the group of archegonia (15 in the case illustrated) surrounds a central mass of sterile tissue. The cutting-off of a ventral nucleus and its rapid disorganization were observed, this division being promptly followed by fertilization during the first week of July. The fusion nucleus soon divides, and the two daughter nuclei pass to the base of the egg. Walls appear after eight nuclei are formed, which is apparently true for Pinaceae without exception. The proembryo comprises three tiers of cell, with the usual functions.—J. M. C.

The ancestor of Pinus.—JEFFREY concludes that Prepinus, a name which he gives to an abietineous form from the Middle Cretaceous of Staten Island (N. Y.), is the direct ancestor of Pinus.[20] It is characterized by deciduous dwarf-shoots, which bore numerous spirally arranged leaves, and it is the structure of these leaves that forms the basis of the claim mentioned. They have paired resin canals continuous to the very base; possess a well-marked centripetal xylem; and about the vascular bundles there is a complicated double sheath of transfusion tissue closely related to the centripetal wood and resembling that found in some of the Cordaitales. It is also shown that many of the true pines of the Middle Cretaceous had the same double "transfusionary foliar sheath," but lacked the centripetal wood. The tissue on the ventral side of the protoxylem in existing coniferous leaves, which has been described by WORSDELL as representing centripetal xylem, JEFFREY regards as a relic of the inner transfusion sheath. In this way he has connected Pinus with the Cordaitales through Prepinus; and has shown that the Mesozoic pines display transition characters between Prepinus and the pines of today. His conclusion is that the Abietineae are the oldest tribe of Coniferales, and that Pinus is its oldest living representative.—J. M. C.

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[19] MIYAKE, KIICHI, The development of gametophytes and embryogeny of Cunninghamia (Preliminary note). Bot. Mag. Tokyo **22**:45–50. *figs. 14.* 1908.

[20] JEFFREY, EDWARD C., On the structure of the leaf in Cretaceous pines. Annals of Botany **22**:207–220. *pls. 13, 14.* 1908.

Aerotropism.—POLOWZOW has taken up the question of the response of plant organs to gases.[21] Reserving the usual term aerotropism for sensitiveness to the mixture of gases that compose the air, he proposes the term *aeroidotropism* for sensitiveness to pure gases. This seems an unnecessary refinement of terms. Very properly he criticizes the use of roots as subjects for experiments with gases, since the organ is under wholly unnatural conditions, and uses stems, which SAMMET tried with negative results. POLOWZOW finds *Brassica Napus, B. Rapa, Vicia sativa, V. Faba, Pisum sativum, Lupinus albus, Phaseolus multiflorus,* and *Helianthus annuus* sensitive to O_2 and CO_2, but unaffected by H and N_2. The grasses studied were all indifferent. At the beginning there is a positive curvature, which becomes more rapid, slows, ceases; shortly a negative curvature sets in, gradually increasing. When stimulation ceases, curvature slows, stops, and then the recovery of the normal position takes place. The active region may be a centimeter or more distant from the perceptive region, which may even be in the part of the stem that has ceased growing, showing that perceptive capacity persists longer than capacity for the curvature reaction. The perception time was found to be 0.5 sec. with 0.01^{cc} of CO_2 and periods of stimulation and rest in the ratio 1:3. The reaction time was found to be not much more than in various tactic responses; POLOWZOW thinks because the movements in both cases were examined by the microscope, and he pleads for the use of the more refined methods of the animal physiologists. There is certainly nothing to prevent; BOSE has blazed the path. We hope that in the full paper to which this is preliminary the the author will give us such records and discuss more fully some general questions he raises.—C. R. B.

Seed production in Pinus.—Under this title HAYDON[22] presents the results of an extended field study supplemented by cytological work. The cytological conditions found in both microsporangiate and megasporangiate cones at various seasons are noted in detail. The staminate cone, in the vicinity of Liverpool, passes the winter in the spore mother cell stage. The megaspore mother cell appears about the end of May, but its origin was not determined. Occasionally large ventral canal cells are formed, and in a few cases the first mitosis in the egg was observed when there were no traces of pollen tubes or other evidences of fertilization. HAYDON believes this supports the suggestion of the reviewer[23] that a large ventral canal nucleus might fertilize the egg. The simultaneous divisions at the base of the egg by which the proembryo passes from the 8-celled stage to the 12-celled stage is sometimes in the lower tier instead of in the upper tier, as is usually the case. Theoretically, the ovulate cone might produce some

[21] POLOWZOW, W., Experimentelle Untersuchungen über die Reizerscheinungen der Pflanzen, mit besonderer Berücksichtigung der Einwirkung von Gasen. Vorläufige Mitteilung. Ber. Deutsch. Bot. Gesells. **26a**:50–69. 1908.

[22] HAYDON, WALTER T., The seed production of *Pinus sylvestris.* (Inaugural address.) Proc. and Trans. Liverpool Biol. Soc. **22**:1–32. *figs. 16.* 1907.

[23] BOT. GAZETTE. **42**:349. 1906.

1500 proembryos, but actually it produces only 10 to 20 seeds. The factors responsible for the difference between the theoretical and the actual output are considered, both in the field study and in the cytological work.—CHARLES J. CHAMBERLAIN.

Geotropic curvature.—PORODKO, reinvestigating the statement of KOHL that "the geotropic curvature extends also to parts of the stem in which growth can no longer be demonstrated," comes to the contrary conclusion, though he does not discover the source of KOHL's error, unless in the fact that he did not use the microscope in his measurements.[24]

BACH's conclusion that the presentation and reaction times for geotropic curvatures are not affected by shaking and jarring, has been welcomed by opponents of the statolith theory of geoperception as depriving it of an important support, though BACH himself does not so use his data. HABERLANDT, whose experiments in shaking and jarring led him to quite the opposite conclusion, reexamines BACH's data, criticizes his methods somewhat, and interprets some of his experiments as showing the very thing which BACH thought they did not show.[25] HABERLANDT also pays his compliments to LINSBAUER, who raised a theoretical objection to the value of the jarring experiments. The statolith theory has a watchful champion, ready to meet all comers.—C. R. B.

A lycopod with a seedlike structure.—Miss BENSON's abstract of her paper on Miadesmia was noticed in this journal.[26] The full paper has now appeared,[27] and the fuller description and plates make the situation more evident. The discovery of the sporophylls of this minute, herbaceous, paleozoic lycopod, has shown a clear relationship to the ligulate Lycopodiaceae, especially Selaginella. The megasporangium produces a single, thin-walled spore, which germinates *in situ*. An integument is developed around the sporangium, leaving a micropyle; and from the surface of the integument numerous long processes develop, giving quite a fringed look to the apparatus. At maturity the sporophyll is shed, the whole structure resembling a winged and fringed seed. The relation of this "integument" to the "velum" of other groups is vague and apparently hardly worth considering; but another case of integumented sporangium, to be added to the previously described Lepidocarpon, is quite worth while.—J. M. C.

Dwarf male prothallia.—BOODLE[28] has observed that if *Todea Fraseri*, a filmy species, be kept in a sufficiently damp atmosphere, the sporangia do not

[24] PORODKO, T., Nimmt die ausgewachsene Region des orthotropen Stengels an der geotropischen Krümmung teil? Ber. Deutsch. Bot. Gesells. **26a**:3–14. 1908.

[25] HABERLANDT, G., Ueber die Einfluss des Schüttelns auf die Perception des geotropischen Reizes. Ber. Deutsch. Bot. Gesells. **26a**:22–28. 1908.

[26] BOT. GAZETTE **44**:318. 1907.

[27] BENSON, MARGARET *Miadesmia membranacea* Bertrand; a new palaeozoic lycopod with a seed-like structure. Phil. Trans. Roy. Soc. London B. **199**:409–425. *pls. 33–37*. 1908.

[28] BOODLE, L. A., On the production of dwarf male prothalli in sporangia of Todea. Annals of Botany **22**:231–243. *pl. 16*. 1908.

dehisce, and spores germinate in the closed sporangia. As a result, dwarf male prothallia are produced, antheridia sometimes appearing at the three- or four-celled stage. Free spores under the same conditions never produce such prothallia, not having developed sexual organs at the conclusion of the experiment. The dwarf males do not burst through the wall of the sporangium, and ultimately die. It was found also that both free spores and those inclosed in sporangia germinate in darkness. The suggested explanation of the formation of the dwarf male prothallia under the conditions described has no foundation in experimental work. It is to be hoped that the day of imaginary "explanations" is about over.—J. M. C.

Periodicity of algae.—BROWN[29] has studied the appearance and disappearance of algae in selected ponds and streams in the vicinity of Bloomington, Indiana. In this region, an alga growing under "steady normal conditions" remains in a healthy vegetative state throughout the year. A sudden change in external conditions checks this vegetative growth, and induces a resting stage or sexual reproduction. In reference to specific plants, *Spirogyra nitida* is the most abundant of the Conjugatae in the region studied, and *S. varians* is the most widely distributed alga, conjugating at all seasons of the year when exposed to hard conditions (as the drying-up of a pond); Chaetophora thrives best in slightly stagnant water at a temperature between 5° and 25° C.; Draparnaldia finds its most congenial conditions in flowing surface water between 1° and 15° C.—J. M. C.

Cytology of Synchytrium.—GRIGGS[30] has continued an investigation on *S. decipiens* begun by F. L. STEVENS, to whom he is indebted for material. There are 500 to 800 free nuclei in the cyst when cell walls begin to appear; but most of the study was upon cysts with 100 to 300 free nuclei. While no centrosomes were found in the metaphase and anaphase, in the telophase there are large asters with centrosomes at the center, whose origin has not yet been determined. As the nuclear vacuole forms about the chromosomes, the coarse rays of the aster bend about it and become transformed into the thick nuclear membrane characteristic of the genus. It is hoped that a further study will throw some light upon systematic relations.—CHARLES J. CHAMBERLAIN.

Sporangia of Lycopodiaceae.—As a result of her study of the sporangium-bearing organs of the Lycopodiaceae, Miss SYKES[31] has arranged the different species of Lycopodium in a continuous series based on the shape and structure of the sporophyll, the position of the sporangium, and the position of the line of dehiscence. The evidence adduced seems scarcely sufficient to warrant the con-

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[29] BROWN, HARRY B., Algal periodicity in certain ponds and streams. Bull. Torr Bot. Club **35**: 223–248. 1908.

[30] GRIGGS, ROBT. F., On the cytology of Synchytrium. Ohio Naturalist **8**: 277–286. *pl. 20.* 1908.

[31] SYKES, M. G., Notes on the morphology of the sporangium-bearing organs of the Lycopodiaceae. New Phytol. **7**: 41–60. *pls. 2, 3.* 1908.

clusion that the genus Lycopodium should be interpreted as a reduction series, or to afford a basis for the supposition that the sporangium-bearing organ of the Lycopodiaceae has been "derived from a branch structure which had the morphological value of an axillary bud."—ALMA G. STOKEY.

Embryo and endosperm of Potamogeton.—COOK[32] has investigated material of *P. lucens* obtained from Cuba. The embryo was found to resemble closely that of Alisma in its development. In endosperm formation a transverse wall chambers the sac at the first division; in the micropylar chamber the endosperm formation proceeds as a series of free nuclear divisions, usually with parietal placing; the antipodal chamber develops as a haustorial extension of the sac into the chalaza, and during this development the second daughter nucleus of the primary endosperm nucleus seems to be very active, but does not divide.—J. M. C.

Ophioglossum simplex.—This rare Sumatran species has been collected again, and these new specimens show to BOWER[33] an outgrowth which, evidently single, represents a sterile blade, of which there was no such indication in the specimen he had examined previously. The fact is important because of the difference of opinion as to the phylogenetic position of Ophioglossum. CAMPBELL has regarded *O. simplex* as the most primitive known member of the genus, while BOWER has claimed it to be a reduction form. The evidence just reported would seem to justify the latter contention.—J. M. C.

Anthocyan and chlorophyll.—An interesting bit on the function of anthocyan is the observation by MOLÉR[34] that the red leaves of a species uniformly contain less chlorophyll than the green leaves. The ratio runs between 1.08 and 1.27. This seems to be difficult to reconcile with TISCHLER's hypothesis that anthocyan enables the plant to nourish itself better and so to stand a more severe climate. —C. R. B.

Radioactivity.—ACQUA reports[35] that salts of uranium and thorium, even in very dilute solutions, injure seedlings of wheat by reducing the development of the primary root. Germination was also retarded. His experiments supplement those on radium and other radioactive substances by other investigators.—C. R. B.

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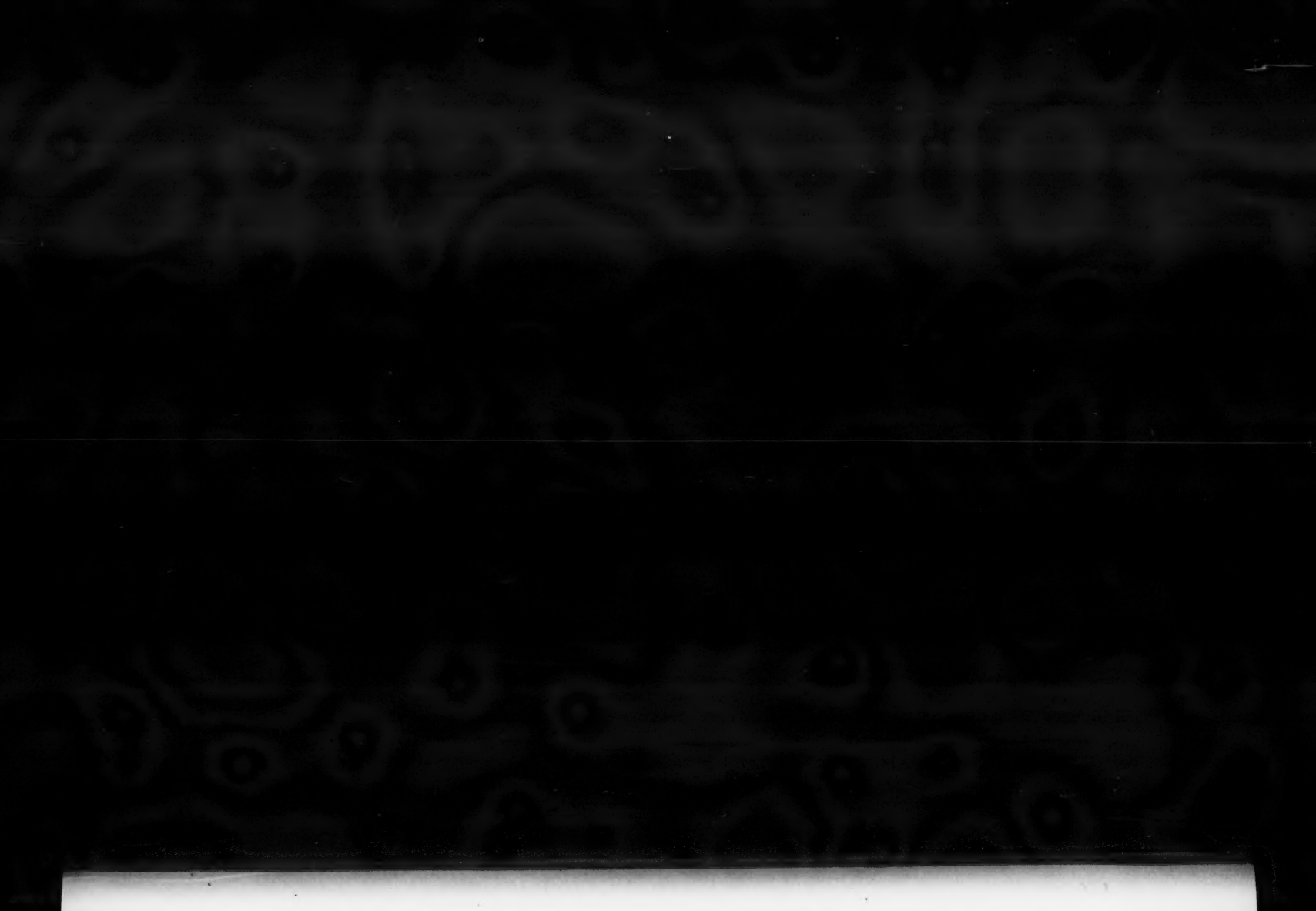
[32] COOK, MELVILLE THURSTON, The development of the embryo sac and embryo of *Potamogeton lucens*. Bull. Torr. Bot. Club **35**: 209–218. *pls. 9, 10.* 1908.

[33] BOWER, F. O., Note on *Ophioglossum simplex* Ridley. Annals of Botany **22**: 327, 328. 1908.

[34] MOLÉR, T., Ueber den Chlorophyllgehalt anthocyanführender Blätter (Vorläufige Mitteilung). Bot. Notiser **1908**: 49–53. 1908.

[35] ACQUA, C., Sull'azione dei sali radioattivi di uranio e di torio nella vegetazione. Annali di Botanica **6**: 387–401. 1908.